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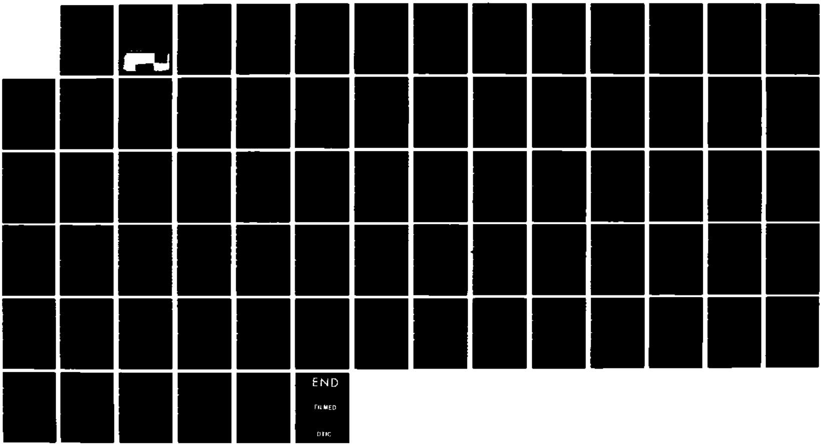

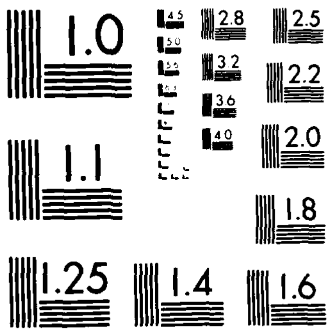

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TECHNICAL REPORT

ANALYSIS OF WARRANTY COST METHODOLOGIES

January 1985

Prepared for
NAVAL MATERIAL COMMAND
COST ANALYSIS DIVISION (MAT-01F4)
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20360
under Contract N00600-84-D-4045
Delivery Order No. 0001
CDRL Item No. A0004

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by

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FOREWORD

Warranty/guarantee provisions have been used in military production contracts for a number of years on a very selective basis. With the passage of Section 794 of the Department of Defense (DoD) Appropriation Act of 1984 (Public Law Number 98-212), it is expected that the use of such provisions will increase significantly. The Act requires warranties for all fixed-price production weapon system procurements unless DoD approves a waiver and advises the Congressional Armed Services and Appropriations Committees.

One of the questions that has repeatedly arisen in the Navy about Section 794 is the potential impact of warranties on the cost of Navy programs. The Naval Material Command Cost Analysis Division (MAT-01F4) has taken the lead in the preparation of warranty cost-estimation procedural guides for Navy programs. The guides are to include effective warranty cost-estimation methodologies for determining if a proposed warranty price is fair and reasonable. In concert with MAT-01F4, the Navy Office of Acquisition Research, Defense Systems Management College, is conducting research and development on warranty cost-estimation methodologies.

This report presents the results of a study that investigated, reviewed, and analyzed methodologies for estimating the cost of warranty provisions that meet the intent of Section 794. The study provides a basis for establishing uniform procedures for estimating the direct cost or price of warranties/guarantees for Navy weapon system procurements. ARINC Research Corporation performed the study for MAT-01F4 under Contract N00600-84-D-4045. The Navy Office of Acquisition Research sponsored the study.

SUMMARY

This report presents the results of a study performed by ARINC Research Corporation to investigate, review, and analyze methodologies for estimating the direct cost (i.e, price) of warranty provisions that meet the intent of Section 794 of the Department of Defense (DoD) Appropriation Act of 1984. The objective of the study was to provide the Naval Material Command Cost Analysis Division (MAT-01F4) the necessary background information and recommended approaches from which uniform procedures can be established for estimating the direct cost of separately priced warranties for Navy programs. The study was monitored by MAT-01F4 and sponsored by the Navy Office of Acquisition Research, Defense Systems Management College.

The study identified and catalogued major warranty provisions for Navy programs to meet the requirements of Section 794. While ARINC Research has significant background and experience in warranty procedures, the study reviewed current DoD and Navy policies and procedures concerning the warranty requirements of Section 794, surveyed industry concerns and Congressional reaction to DoD implementation of Section 794, and established a data base on DoD and Navy warranty procurements. These activities ensured that all feasible warranty concepts were identified and that the most recent implications of Section 794 were considered in the study. From the surveys and reviews conducted, more than twelve categories of warranty provisions were identified (Chapter Two, Table 2-3) as being consistent with Section 794.

In addition, each type of warranty provision was examined for characteristics that determine contractor obligations under Section 794 to guarantee that the weapon system and components are designed and manufactured to the Government's specified performance requirements and that the system and components are free from defects in materials and workmanship. On the basis of these obligations, the study identified major warranty-cost data items and variables to characterize the cost of resources that the contractor will require for furnishing the warranties and guarantees. It was assumed that a contractor supplying the warranties would estimate all costs associated with these resources and that these costs, augmented by profit and perhaps risk factors, would normally be included in the bid price. A classification scheme is provided in Chapter Two (Table 2-5) for nine major types of data items that may support the estimation of total contractor costs for warranties/guarantees.

The study surveyed, identified, and assessed methodologies that show promise as uniform Navy procedures for estimating the price of the warranty requirements of Section 794. The study identified no standard warranty price/cost-estimation model currently being used on Navy procurements. The same situation was also found to be true for other DoD procurements. However, several ideas and concepts have been in existence for years, and the study determined that their application now would be particularly appropriate. The study assessed three warranty pricing methods that are available or could be developed as candidates for Navy application: the Air Force RIW pricing model, warranty price ratio, and warranty cost-estimating relationships. These methods are examined fully in Chapter Three for their logic of approach, accessibility of required data, complexity, accuracy potential, suitability to Navy programs, and potential for generalization to uniform procedures.

On the basis of the warranty provisions catalogued, the major cost data items identified, and the warranty pricing methods assessed in Chapters Two and Three, the study resulted in recommendations of the most promising procedures for warranty price estimation for Navy programs. It was intended that the recommendations would form a basis for establishing uniform Navy procedures and guidelines. Recommended were the rule-of-thumb ratio, warranty cost-estimating relationships, and a bottom-up accounting model. The three methodologies vary greatly in the amount of detail they provide and the quantity of data that would be required to make the best use of them. Chapter Four describes these methods in detail.

Finally, the study provided recommendations of useful areas of development that would be particularly beneficial to MAT-01F4 in the preparation of warranty cost-estimation procedural guides for Navy programs. Chapter Five discusses the recommendations, which encompass three areas:

- Warranty Benefit Analysis. A study of methodologies is recommended to determine the cost-effectiveness or value of a warranty. Techniques should be investigated to estimate total system life-cycle costs, both with and without a warranty, and then the difference should be calculated.

- RIW Model Enhancement. The Air Force RIW price model has been determined to be a detailed, available model for estimation of warranty costs. It will require enhancement to incorporate procedures for estimating the costs of design and manufacture guarantee, Government-furnished property, consignment spares, and warranty price adjustments to be sufficient for Navy programs under the requirements of Section 794. Such enhancement is feasible and is recommended.

- Data Analysis. Numerical data are necessary for the follow-on steps of model calibration and validation, as well as for the calculation of default values. Data analysis will be useful in conducting order-of-magnitude studies, performing trend analysis, and ensuring that the methodologies identified in this study can be applied practically and conveniently.

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CHAPTER ONE

INTRODUCTION

Warranty/guarantee provisions have been used in military production contracts for a number of years on a very selective basis. With the passage of Section 794 of the Department of Defense (DoD) Appropriation Act of 1984 (Public Law Number 98-212), it is expected that the use of such provisions will increase significantly. The Act requires warranties for all fixed-price production weapon system procurements unless DoD approves a waiver and advises the Congressional Armed Services and Appropriations Committees.

The Deputy Chief of Naval Material (Contracts and Business Management) requested that the Deputy Chief of Naval Material (Resources Management) review the subject of cost estimation for warranties for Navy programs in light of the recent Congressional action and publish uniform procedures for estimating such costs (Ref. 1*). The Deputy Chief of Naval Material (Resources Management) agreed that the Cost Analysis Division (MAT-01F4) should work with the Deputy Chief of Naval Material (Contracts and Business Management) on warranty cost-estimation policy issues and take the lead in preparing cost-estimation procedural guides (Ref. 2). In concert with MAT-01F4, the Navy Office of Acquisition Research, Defense Systems Management College, is conducting research and development on warranty cost-estimation methodologies.

Under Contract N00600-84-D-4045, ARINC Research Corporation assisted MAT-01F4 in the investigation, review, and analysis of methodologies for estimating the direct cost (i.e., price) of warranty provisions that meet the intent of Section 794. The Navy Office of Acquisition Research sponsored the study. This report presents the results of that study effort.

1.1 BACKGROUND

In the 1984 DoD Appropriation Act and the 1985 DoD Authorization Act, Congress has enacted warranty requirements legislation affecting the military acquisition system. Section 794 of the 1984 Act states in part that "no funds may be obligated or expended for the procurement of a weapon

*All references in this report are listed in Chapter Seven.

system unless the prime contractor or other contractors for such system provide the United States with written guarantees."* The guarantees must stipulate that:

- The system and the components thereof were designed and manufactured so as to conform to contractual performance requirements.

- The system and components are free from all defects (in materials and workmanship) that could cause failure to meet performance requirements.

- In the event of failure, the contractor will bear the cost necessary for achieving required performance.

In terms of warranty requirements legislation, there is no principal difference between Section 794 and the 1985 DoD Authorization Act. The new legislation under the 1985 Act (effective 1 January 1985) is designed to give DoD more flexibility in applying warranties to weapon system procurements. The conference report of the 1985 Act adds a new Section 2403 to Title 10 of the United States Code. New and revised warranties language and provisions that are defined in Section 2403 include the following:

- Exemption of the first 10 percent of total weapon system procurement from essential-performance warranty requirements or the initial production, whichever is less

- A dollar threshold that requires procurements to be warranted for systems costing more than $100,000, or systems for which the eventual total procurement cost is more than $10 million

- DoD option of having the contractor either perform warranty work or provide payment for Government performance of warranty work

This report will continue to refer to Section 794 in discussing warranty requirements and note other changes from Section 2403 as appropriate.

One the questions that has repeatedly arisen in the Navy about the requirements of Section 794 is the potential impact of warranties on the cost of Navy programs. MAT-01F4 has taken the lead in the preparation of warranty cost-estimation procedural guides for Navy programs (Ref. 2). It was realized that Navy program managers will need supporting cost data and procedures to determine the warranty coverage and period that will be most economically attractive.

In enacting the recent Section 2403 warranty requirements, Congress voiced strong concern regarding the issue of warranty cost-effectiveness (Ref. 3). It first questioned the fact that virtually no waivers were

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*It is common in current DoD usage to use the terms "guarantee" and "warranty" interchangeably.

to cover the added risks in a "performance requirements" guarantee for "design and manufacture" liabilities.

2.2.2 Specified Performance Requirements

The characteristics of specified performance requirements to be guaranteed will depend on the application at hand, since each Navy procurement is unique. The DoD Guidance provides that the requirements should be "realistic and achievable and accurately reflect the need for the weapon system." In addition, they should be "significant," which implies that minor requirements are not required by the DoD Guidance to be guaranteed by the contractor.

In Section 2403, the term "essential performance requirements" is used with respect to the operating capabilities or maintenance and reliability characteristics of the system. Congress believes that Section 794 and Section 2403 provide "inherent flexibility" to tailor performance guarantees appropriate to the level of contractor design involvement (Ref. 3).

In most Navy procurements, it can be expected that the specified performance requirements will relate predominately to equipment performance. The characteristics of equipment performance for aircraft engines, for example, would include such parameters as fuel consumption, engine shutdown rate, and engine thrust performance. An equipment performance warranty may require that "significant" performance parameters be successfully measured during the warranty coverage.

In addition to equipment performance, other performance agreements may exist in the procurement of a weapon system. These agreements would also require suitable warranties which meet the intent of Section 794. Three types of performance warranties that have received the greatest attention to date in DoD procurements are reliability improvement warranty (RIW), mean time between failures (MTBF) guarantee (MTBFG), and logistics support cost (LSC) commitment. The salient features of each are summarized in Table 2-4.

The following discussion briefly highlights typical applications of RIW and MTBFG warranties for improving the reliability performance of weapon systems. Reliability, in particular, is an elusive parameter -- difficult to define, estimate, and measure. It is not uncommon for field reliability to be one-third or less of that exhibited through a MIL-STD-781 demonstration test. A contractor generally does not have an inherent motivation to spend any more effort on reliability than is necessary to pass the MIL-STD-781 test. The typical DoD acquisition process does not provide the commercial marketplace environment that can assign a valuable premium to producers of highly reliable equipment.

With a properly structured warranty, the contractor is obligated to deliver. Consider the RIW form of warranty. Here the equipment is covered for a long duration, typically three or more years with a contractor commitment for depot-type repair. The price paid for the RIW should be related to a specified or negotiated field reliability level. If the actual reliability is less than the target, then more failures occur and

TABLE 2-3

MAJOR WARRANTY/GUARANTEE PROVISIONS

Warranty Statement	Transportation
Specified Performance Requirements	Warranty Pipeline Flow
Warranty Duration	Warranty Data
Contractor Repair Obligation	Government-Furnished Property
Exclusions	Government Obligations
Unverified Failures	Other Provisions

The warranty provisions in Table 2-3 are best reviewed by highlighting the major features. The following subsections discuss these features, which will determine contractor obligations in providing guarantees that meet the intent of Section 794. These obligations, together with other factors to be discussed in Chapter Three, will for the most part determine the contractor-proposed warranty price.

2.2.1 Warranty Statement

The warranty statement indicates that the contractor warrants that the equipment furnished under the contract will conform to specified performance requirements. The DoD Guidance requires the contractor to guarantee that the weapon system and components are "designed and manufactured" to the Government's specified performance requirements, and that the system and components are free from defects in "materials and workmanship." It further requires that the contractor "bear the cost of all work and promptly repair or replace such parts as necessary to achieve the required specified performance requirements."

Warranty requirements under Section 794 represent a considerable expansion of the previous Defense Acquisition Regulation (DAR) policy, which used warranties selectively at the subsystem and component levels rather than at the full system level. A further major distinction is that Section 794 imposes a "performance requirements" guarantee that is, for the most part, new to weapon system procurements. This guarantee could require the contractor to perform system redesign and remanufacture at its own expense in the event the system fails to conform to the Government's specified performance requirements during the warranty coverage period. Therefore, it can be expected that the contractor will price its warranty

TABLE 2-2 (continued)

Item Description (Service)	Warranty Provision	Warranty Award Date	Unit Quantity	Average Years/Hours	Set Unit Price (Dollars)	Warranty Price per Year (Dollars)	Warranty Price per Year as Percent of Set Unit Price
AN/APN-128 Navigation System (Army)	RIW with MTBF guarantee	1976	200	4.0 yrs	23,495	269	1.1
		1979	381	4.0	18,252	169	0.9
		1981	219	4.0	18,252	169	0.9
		1981	222	4.0	38,050	519	1.4
		1981	102	4.0	37,850	425	1.1
		1982	211	4.0	35,900	425	1.1
		1982	327	4.0	35,900	425	1.1
		1983	4	4.0	35,900	425	1.1
		1983	3	4.0	35,900	425	1.1
F-16 Avionics (Air Force)							
Inertial Navigation Unit	RIW	1977	442	4.0 yrs	166,000	4,067	2.4
Flight Control Computer	RIW	1977	442	4.0	55,000	1,375	2.5
Head Up Display Unit	RIW/MTBF	1977	442	4.0	80,000	5,525	6.9
Radar Unit	RIW	1977	442	4.0	565,000	13,908	2.5
AGM-65 Maverick (Air Force)	Performance and defects	1984					
Launcher Electronic Unit (LEU)			750	1.0 yr	11,694	29	0.2
LEU Data			1	1.0	63,088	1,000	1.6
LEU Production Test Equipment			1	1.0	325,559	5,000	1.5
Hell Fire Launcher (Army)	Performance and defects	1984	561	1.0 yr	25,000 (3) 9,830 (558)	5	0.1 (avg)
Mine Neutralization System (Navy)	Performance and defects	1984	6	3.0 yrs	3,714,822	27,678	0.7
Cruise Missile Shipboard Control Center (JCMPO)	Performance and defects	1984	4	3.0 yrs	2,378,857	25,000	1.0 (avg)
Cruise Missile Ground Control Center (JCMPO)	Performance and defects	1984	60	1.5 yrs	1,245,430	4,445	0.4 (avg)
Cruise Missile Engine (JCMPO)	RIW/AG	1984	579	6.0 yrs	195,000	1,727	0.9 (avg)
	Performance and defects	1984	579	1.0 yr	195,000	432	0.2 (avg)
WPU-5/B Missile Propulsion Section (NAVAIR)	Manufacture and defects	1984	2,000	3.0 yrs	5,500	13	0.2
AN/SRC-47(V) Flight Deck Comm System (NAVELEX)	Defects	1984	7	3.0 mos	1,426,291	14,286 (3 Mos)	4.0 (avg)

TABLE 2-2

SUMMARY OF DOD WARRANTIES

Item Description (Service)	Warranty Provision	Warranty Award Date	Unit Quantity	Average Years/Hours	Set Unit Price (Dollars)	Warranty Price per Year (Dollars)	Warranty Price per Year as Percent of Set Unit Price
ARN-118(V) TACAN	RIW with MTBF	1975	1,000	4.5 yrs	9,448	680	7.2
(Air Force)	guarantee		2,487	4.5	9,039	400	4.4
			2,499	4.5	8,504	350	4.1
			1,600	4.5	8,909	476	5.3
F-111 Gyro SBK-11/A24G-26	PPW with TAT	1970	23	5/3,000	6,040	440	7.3
(Air Force)	requirements	1970	168	5/3,000	6,040	440	7.3
		1971	168	5/3,000	6,040	440	7.3
		1972	158	5/3,000	6,040	440	7.3
		1973	84	5/3,000	6,040	440	7.3
ARN-123 VOR/ILS	RIW with MTBF	1976	1,139	4.0 yrs	1,377	148	2.7
R-1963 Glideslope/Marker Beacon	guarantee	1976	465	4.0	682	61	2.2
(Army)	(no spares)						
Inertial Navigation System	RIW	1978	174	4.0 yrs	54,891	3,393	6.2
(Air Force)		1978	258	3.16	54,063	2,292	5.5
Attitude and Heading Reference	RIW	1976	9	5.0 yrs	25,000	1,580	6.3
System (Air Force)		Option	76	5.0	13,170	1,580	11.9
		Option	43	5.0	12,730	1,580	12.4
		Option	86	5.0	12,790	1,580	12.3
		Option	61	5.0	12,540	1,580	12.6
Omega Receiver	RIW with MTBF	1977	4	5.0 yrs	10,430	532	5.1
(Air Force)	guarantee	1977	242	5.0	10,430	532	5.1
		Option	1-1,200	3.5	7,950/7,077	378/269	4.7/3.8
AN/APN-209 Altimeter (Army)	RIW						
R/T		1976	290	3.5 yrs	4,412	374	8.5
Antenna		1976	580	3.5	105	3	2.7
Remote Indicator		1976	118	3.5	1,738	188	10.8
R/T		1977	1,188	2.7 yrs	4,412	326	7.9
Antenna		1977	2,376	2.7	105	2	1.4
Remote Indicator		1977	344	2.7	1,738	72	4.1
R/T		1978	492	2.0 yrs	4,412	285	6.5
Antenna		1978	894	2.0	105	2	1.4
R/T		Option	1,000	2.0 yrs	4,024	243	6.0
Antenna		Option	2,000	2.0	105	2	1.4
Remote Indicator		Option	246	2.0	1,586	78	4.9

(continued)

2.1.5 DoD Procurements with Warranties

In addition to the survey and review activities described, we also surveyed previous and available recent DoD procurements for which warranties were furnished. Table 2-2 summarizes the DoD procurements surveyed and compares the types of warranty plans used and the price of the warranties. In addition to the cost information, we collected other available information on the extent of warranty coverage, the procurement environment, the equipment, and the expected user environment. The warranty data collection form used in the survey is presented in the Appendix for reference.

The data collected to date are not sufficient to establish statistically significant conclusions. The data are limited and preliminary; further data collection efforts are required. However, it can be stated that, on the basis of the information in Table 2-2, warranty price per year as a percentage of unit price ranges from 0.1 to 12.6 percent; the average over 56 item-years is 4.1 percent. Some of the award dates are after March 1984, so there have been some reasonable warranty provisions issued since the passage of Section 794 of the DoD Appropriation Act of 1984.

Industry concern about affordable warranties, as discussed in Section 2.1.2, is not evident in Table 2-2. For example, the 1984 procurements for the cruise missile shipboard/ground control centers and the cruise missile engine were negotiated with a warranty price per year of 1 percent of set unit price or less for each procurement. Both procurements included complex warranties with extensive warranty coverage that fully comply with Section 794 requirements and run for several years.

2.2 SUMMARY OF WARRANTY PROVISIONS

On the basis of the reviews and surveys conducted, as well as the DoD procurements summarized in Table 2-2, it is recognized that warranty provisions depend on economic, procurement, logistics, equipment, and administrative aspects of individual weapon system programs. Therefore, a standard set of provisions applicable to all weapon system procurements would be extremely difficult to establish. We concur with Congress that "each warranty situation is unique" (Ref. 3) and would require negotiation of warranties on a case-by-case basis. However, a basic set of provisions can be determined from past DoD warranty experience and outlined to indicate the major ramifications and alternatives. The provisions are presented in Table 2-3.

A draft version of the DoD supplement to the Federal Acquisition Regulation (FAR) has been prepared to provide guidance on warranties application in weapon system procurements. At the time of the writing of this report, the draft was being reviewed by Congress and was unavailable for public review. It is assumed that the provisions indicated in Table 2-3 will generally reflect the guidance in the upcoming DoD FAR supplement.

clause applies to both performance parameters and workmanship and materials.

- Missile warranties, as in the cases of HARM and HARPOON, are tailored to cover both all-up rounds and sections delivered for assembly over extended periods of time and tested during storage.

- Engine warranties provide comprehensive extended coverage for both performance and workmanship.

- Subsystems, such as avionics, treat performance parameters as defined in the specification and measured at acceptance, and are tailored in their coverage of materials and workmanship for periods of 12 months or longer.

AIR 51654 added that the basic premise behind NAVAIR's warranty plan is to get the contractor to stand behind its product and extend its responsibility to fleet performance.

The Naval Sea Systems Command (NAVSEA) implementation approach to warranties is addressed in a SEA 02 memorandum (Ref. 7) that provides information concerning the DoD Guidance on warranties for defense contracts. The memorandum refers to the DoD Guidance for warranty implementation until further guidance is received from the Chief of Naval Material. Specific cost considerations are emphasized, however:

- Both the period and dollar liability under the warranty provisions may be capped at reasonable levels.

- Warranty costs are to be considered and tracked throughout the life of a contract.

- Warranties are to be separately priced where possible.

- Cost-effectiveness is to be a prime consideration in contract negotiations.

- Effects on other factors (e.g., logistics, spares breakout, competition) must be considered.

The memorandum concludes that the effects of Section 794 on NAVSEA are largely unknown. It advises that contractors are expected to take a conservative position regarding liabilities under warranty until they have gained substantial experience.

The Naval Electronic Systems Command (NAVELEX) implementation approach to warranties is similar to that of NAVSEA. In addition, ELEX 260 is providing a professional seminar for command personnel to review and discuss the implications of Section 794 on Navy weapon system procurements.

length. A number of concerns are expressed about the manner in which warranties under Section 794 are applied in DoD procurements. These concerns include the following:

- Warranties are being applied using a warranty clause with no adjustment in terms.

- Contractors may be called on to guarantee the performance of systems for which they may have had limited design responsibility.

- Waivers are not being processed for warranties that are not cost-effective.

The conferees respond to these concerns with specific comments on the approach that Congress had anticipated for warranties to be applied.

The conferees strongly agree that weapon system warranties should be negotiated on a case-by-case basis. They believe that Section 794 and Section 2403 provide "inherent flexibility" for tailoring warranties to such factors as whether a system is expendable (such as a missile) or non-expendable; what the logistical support capabilities of both the Government and the contractor are; and the extent to which the contractor has designed the system. The conferees further emphasize that Section 2403 clearly provides DoD with the authority to negotiate reasonable exclusions, limitations, and time durations on warranties.

The conferees agree that DoD should have the "authority in crafting specific warranties to consider the formulation of exclusions or limitations to address situations where a contractor has not designed a system." They believe that DoD could, under Section 794 and Section 2403, "narrow the scope of warranties if it would be inequitable to require a warranty of all essential performance requirements because of a lack of contractor design involvement."

The conferees advise that "a failure to conduct cost-benefit analyses and to process waivers where cost-effective guarantees are not obtainable would defeat the legislative intent of Congressional warranty initiatives." It is noted that virtually no waivers have been processed since Section 794 was enacted into law. As a result, the conferees "direct each of the military departments to establish mechanisms for effective cost/benefit analyses of proposed weapon system guarantees."

2.1.4 Navy Approach to Warranties

In an interview with AIR 51654, ARINC Research discussed the Naval Air Systems Command (NAVAIR) implementation approach to Section 794 warranty requirements. In summary, the plan is based on fixed-price production contracts, and addresses both performance parameters and defects in workmanship and materials for aircraft, engines, missiles, and subsystems in tailored variations, as follows:

- Aircraft weapon systems have long been warranted under a Defense Acquisition Regulation clause covering correction of defects. The

- It is anticompetitive and will accelerate the erosion of the industrial mobilization base due to the inability or unwillingness of many firms to accept or discharge the onerous performance guarantees.

- It will inhibit technical innovation.

- Implementation of Section 794 would require development by DoD of a data system to provide for warranty performance data collection. Such a system would be complex and very expensive, and would take a long time to implement. Without such a system, warranty performance could not be monitored properly.

In addition to these reasons for the repeal of Section 794, CODSIA adds that, "what industry cannot provide, at affordable cost, is a continuing guarantee of product performance when the contractor does not control design, changes, or operational performance."

CODSIA is also critical of the DoD Guidance. It believes that the regulations of the guidance "exacerbate, rather than moderate, the effect of Section 794." There is a strong concern that the proposed guidance has gone far beyond the Section 794 statutory remedy for failure, which, according to CODSIA, is "parts repair or replacement, no more and no less." CODSIA criticizes the guidance as follows:

- It has, in effect, provided in Section 5(a) for system redesign and remanufacture.

- It has provided for the performance of all corrective work "at no cost to the government," a requirement that is inconsistent with the philosophy and policy relating to cost reimbursement and flexibly priced contracts.

- It has gratuitously imposed on the contractor (in the model clause) round-trip transportation costs for items returned to the contractor, notwithstanding the circumstances.

- It has added requirements for data and reports.

- It has given itself the added option of a price reduction.

CODSIA advises that guarantees that include redesign, redevelopment, retest, and retrofit "would become so expensive as to assure the need for a cost effectiveness waiver in virtually every case." It further adds that guarantees with these remedies "may be expected to encounter strong resistance from many sources, but especially among suppliers."

2.1.3 Congressional Reaction to DoD Implementation of Section 794

In the conference report (Ref. 3) of the 1985 DoD Authorization Act, the Congressional conferees discuss the matter of warranties at some

TABLE 2-1

SUMMARY OF GAO REVIEW OF DoD GUIDANCE

	Questions	Answer
1.	May the Secretary of Defense delegate his authority to waive the guarantee requirements?	Yes
2.	Are "class waivers" permissible under Section 794?	Yes
3.	Is a class waiver for all cost-reimbursement contracts permissible under Section 794?	Yes
4.	Should DoD have provided guidance concerning subcontractor guarantees?	No
5.	Does DoD have authority under Section 794 to require a contractor to redesign defective parts and a weapon system?	Yes
6.	Can DoD include the following provisions in the model guarantee clause, incident to enforcement of the guarantees: (1) the contractor will bear all transportation costs for returned items; (2) the contractor will bear the cost of preparing and furnishing reports on correction taken pursuant to the clause; and (3) the Government shall be entitled to an equitable adjustment in the price of supplies if it decides not to require repair or replacement of parts?	Yes
7.	In light of Section 794(b) exclusion of Government-furnished property (GFP) from guarantee coverage, can the model guarantee clause extend the guarantee requirements to the contractor's installation or modification of such property?	Yes
8.	Does Section 794 preclude the exclusion of liability for loss, damage, or injury to third parties and consequential damages from the coverage or the guarantee?	Yes
9.	Can the model guarantee clause exclude "goals or objectives" from the term "performance requirements"?	Yes
10.	Does DoD have authority to limit the duration of guarantees?	Yes

The GAO review of the DoD Guidance focused on whether the warranty provisions of the guidance are consistent with and do not exceed the requirements of Section 794. The objective of the review was to determine "whether DoD actions were arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." Specifically, GAO considered a number of legal questions raised by the guidance. Table 2-1 summarizes those questions and the overall GAO answers. GAO concluded that the DoD Guidance and model guarantee clause are consistent with and do not go beyond the requirements of the Section 794 statute.

2.1.2 Industry Concerns About DoD Warranties

DoD sent the proposed version of the DoD Guidance to industry associations for comment. In addition, the proposed guidance was published in the 20 January 1984 issue of the Federal Register with the request for public comment.

In general, the Section 794 warranties provision and the DoD Guidance have been widely criticized by industry officials. The views of the Council of Defense and Space Industry Associations (CODSIA) express, for the most part, the concerns of the defense industry. These views (Ref. 6) are those of the following members of CODSIA: Aerospace Industries Association, National Security Industrial Association, Electronic Industries Association, and Shipbuilder's Council of America.

CODSIA believes that "Section 794 is so vague, costly and unworkable that it is not susceptible of implementation." It would like to see the repeal of the Section 794 warranties provision for the following reasons:

- It implies a surrender by DoD of control over the development and acquisition process, which is inconsistent with professional and DoD discretion in determining how defense needs will be met.

- It is inconsistent with cost-type and incentive-type contracts in which the Government shares cost and performance risks.

- It imposes a high-cost "performance requirements" guarantee, which is new to weapon system contracts.

- It leads prime contractors to an inevitable reduction of approved sources for spare parts and repair services, effectively negating Congressional, DoD, and industry initiatives to reduce cost and help small businesses by increasing competition.

- It attempts to equate weapon system guarantees with an idealized conception of commercial product warranties, which are not comparable. Commercial manufacturers control the design, development, volume production, and pricing of their products that embody mature technology. These attributes are not found in the weapons system acquisition process.

CHAPTER TWO

WARRANTY PROVISIONS AND COST VARIABLES

This chapter identifies warranty provisions for meeting the requirements of Section 794 in Navy procurements, and identifies major data items and variables required to estimate total contractor costs for alternative warranty provisions. Section 2.1 discusses the activities that were conducted to identify the various types of warranty provisions, Section 2.2 summarizes the warranty provisions identified, and Section 2.3 identifies major data items and variables for estimating total contractor costs for alternative warranty provisions.

2.1 IDENTIFICATION OF WARRANTY PROVISIONS

In conducting this study, we first reviewed the DoD "Guaranty Policy Guidance" (Ref. 4), effective 14 March 1984, for implementing the warranty requirements of Section 794. Included in the guidance is a model clause that may be used in procurement contracts. We then investigated the following areas:

- General Accounting Office (GAO) analysis of DoD Guidance
- Industry concerns about DoD warranties
- Congressional reaction to DoD implementation of Section 794
- Navy approach to warranties
- DoD procurements with warranties

The following subsections discuss the insights that these investigative efforts provided about the implications of Section 794 concerning warranty provisions in Navy weapon system procurements.

2.1.1 GAO Analysis of DoD Guidance

At the request of the Senate Subcommittee on Defense Committee on Appropriations, GAO conducted a legal review of the DoD Guidance (and attached model guarantee clause) implementing Section 794. The review (Ref. 5) provided this study effort with important background information on warranty provisions that may be included in Navy weapon system procurements.

costs for alternative warranty provisions. Chapter Three identifies and assesses warranty cost-estimation methodologies. Chapter Four recommends potentially effective warranty cost-estimation methodologies for Navy programs. Chapter Five presents a discussion of areas in which further analysis and development could lead to the establishment of uniform procedures for estimating warranty costs for Navy programs. Chapter Six presents conclusions and recommendations based on the results of the study. Chapter Seven lists references used in the study effort. The Appendix is a warranty cost data collection form used to collect available information on DoD warranted procurements. The form shows the extent of warranty coverage, the procurement environment, the equipment, and the expected user environment.

DoD and Navy procurements that provides the warranty terms and conditions in production contracts awarded, the warranty prices paid, and information on factors in the acquisition environment that may have influenced the warranty structure and pricing. Part of the data base includes the significant background and experience of ARINC Research in warranty studies of DoD procurements during the past 15 years.

From the surveys and reviews conducted, we outlined a basic set of warranty provisions for meeting the warranty requirements of Section 794. Each type of warranty provision was examined for characteristics that will determine contractor obligations to guarantee that the weapon system and components are designed and manufactured to the Government's specified performance requirements, and that the system and components are free from defects in materials and workmanship. On the basis of these obligations, we identified major warranty cost data items and variables to characterize the cost for resources that the contractor will require for furnishing the warranties and guarantees. A classification scheme was produced for the different types of data items that may support the estimation of total contractor costs for warranties/guarantees.

1.2.2 Assessment of Warranty Cost-Estimation Methodologies

ARINC Research surveyed, identified, and assessed warranty cost-estimation methodologies that show promise as uniform procedures for Navy programs. The survey incorporated our previous experience with warranty pricing and the results of interviews with available Navy and DoD offices cognizant of warranty application. We examined the various methodologies for logic of approach, accessibility of required data, complexity, accuracy potential, suitability to Navy programs, and potential for generalization to uniform procedures.

1.2.3 Recommendations of Effective Warranty Cost-Estimating Methodologies

On the basis of the assessments previously conducted, we determined that three methodologies show promise as uniform cost-estimation procedures for Navy programs. It is anticipated that these methods will be applied to determine if a proposed warranty price is fair and reasonable. Recommendations were made regarding the next steps to be taken to lead to development of uniform Navy procedures.

1.2.4 Recommendations of Further Analysis and Development

We identified aspects of the methodologies that could benefit from further analysis. The topics of warranty benefit analysis, model enhancement, and data analysis were explained, and recommendations for further development were made.

1.3 REPORT ORGANIZATION

Chapter Two of this report identifies and catalogs warranty provisions that meet the requirements of Section 794 for Navy programs, and identifies major data items and variables required to estimate total contractor

processed since Section 794 was enacted into law, and added that the Committees on Armed Services have never intended that guarantees which are not cost-effective should be obtained. As a result of this concern, Congress has directed each of the military departments to establish mechanisms for effective cost/benefit analyses of proposed weapon system guarantees.

The study presented in this report addresses cost-estimation methodologies concerning the direct cost or price of a warranty. The price of a warranty represents one of a number of cost factors that should be analyzed in determining whether a warranty is cost-effective. Other cost factors may include the cost differential between warranty support and organic maintenance, program costs to administer and enforce a warranty, and lost-opportunity costs on competition of components or spares that would have to be purchased only from the contractor so as not to void the warranty. The results of this study effort will support other activities of MAT-01F4 in the preparation of Navy procedural guides for assessing the incremental cost of implementing Section 794.

1.2 STUDY OBJECTIVE AND APPROACH

The objective of this study effort is to provide MAT-01F4 the necessary background information and recommended approaches from which uniform procedures can be established for estimating the direct cost of separately priced warranties for Navy programs. The study addresses the following areas:

- Identification of provisions and cost variables for meeting warranty requirements of Section 794

- Assessment of cost-estimation methodologies for potential as Navy uniform procedures for estimating the direct cost or price of Section 794 warranties

- Recommendations of effective warranty cost-estimating methodologies for Navy programs

- Recommendations of further analysis and development on the preparation of warranty cost-estimation procedural guides for Navy programs

These areas are discussed in the following subsections.

1.2.1 Identification of Warranty Provisions and Cost Variables

ARINC Research reviewed current DoD and Navy policies and procedures concerning the warranty requirements of Section 794. The review provided information on the manner in which Section 794 is to be implemented in weapon system procurements. In additior, industry concerns and Congressional reaction to the implementation of Section 794 were reviewed.

We also surveyed and reviewed recent DoD procurements implementing the warranty requirements of Section 794. We established a data base on

TABLE 2-4

FEATURES OF ALTERNATIVE PERFORMANCE WARRANTIES

Features	RIW	MTBF Guarantee	LSC Commitment
Objective	Secure reliability improvement; reduce support costs	Achieve stated reliability requirements; reduce support costs	Achieve stated logistics cost goal
Method	Contractor repairs or replaces all applicable items that fail during coverage period; contractor implements no-cost ECPs to improve reliability/maintainability	Guaranteed field MTBF stipulated; contractor provides consignment spare units to maintain logistics pipeline if guarantee is not met; spares are kept by Government if MTBF does not improve	Normal military maintenance; operational test using a specific model is performed to assess LSC; penalty or corrective action is required if goals are not achieved
Pricing	Fixed price	Fixed price	Fixed price or limited cost sharing for correction of deficiencies
Incentive	Contractor profits if costs are lower than expected because of improved R&M	Severe penalty for low MTBF; can include a positive incentive if MTBF exceeds guarantee value	Award fee if goal is bettered; penalties for poor cost performance

the contractor will have to pay for additional repair out of its profits. If the reliability level is better than the target, the contractor keeps some of the RIW money as additional profit. The RIW concept can therefore provide very positive motivation to contractors to provide extra design, test, and production efforts to ensure that field reliability is satisfactory.

In some contracts, RIW and MTBFG approaches have been used together. The contractor warrants that the equipment will perform as specified for X years. If the equipment fails, the contractor will repair or replace it at no additional cost to the Government under the RIW form of warranty. The contractor also guarantees through the MTBFG form of warranty that the equipment will have a field MTBF of H hours. If the measured MTBF is less than H, then the contractor will perform the actions necessary to correct the problem. Until the MTBF requirement is met, the contractor provides consignment (loaner) spares to compensate for the reduced readiness caused by the low MTBF. If the MTBF is greater than H, a monetary incentive may be provided.

2.2.3 Warranty Duration

In DoD warranty contracts, the period of coverage is often stated in terms of calendar time, operating hours, or a combination of these parameters. The best way to define a period of coverage depends on the application at hand. Warranty duration normally begins at the time of

Government acceptance. In defining the period of coverage, the following factors may be considered:

- Installation or Deployment Schedule. Occasionally, equipment will be put into operation shortly after Government acceptance. If this is not the case for a particular procurement (e.g., installation of ship systems), then the warranty period could be extended to some time after first substantial use or, more specifically, some time after deployment of the N^{th} item.

- Operating Rate. For equipments that operate on a shift basis or a regular number of hours per month (as avionics equipments tend to be used), it may be possible to define a total number of operating hours (or maximum time interval) as the period of coverage. Then estimates of actual total usage can be made on the basis of either field surveys or usage rates observed from failed and other returned units. For items with irregular or unpredictable usage rates, it may be more appropriate to cover each item for X operating hours or Y years, whichever occurs first.

In each case, the objective is to give the contractor a picture of the expected usage under warranty. Thus, the contractor is better able to estimate risk exposure, increasing its ability to price the warranty commitment.

2.2.4 Contractor Repair Obligation

Under the warranty, failed equipment is normally returned to the contractor's repair facility for repair or replacement. The DoD Guidance provides that the contractor should repair or replace the failed equipment "promptly as required by the contract" or reimburse the Government for cost incurred by the Government in procuring parts and materials from another source and accomplishing the repair. However, the recently enacted Section 2403 will require the Government to have both options available regardless of the "promptness" of contractor actions.

In addition to the repair or replacement requirement, the contractor is also obligated to "perform all design (subject to Government approval) and manufacture work as necessary" for the system to conform to the Government's specified performance requirements during the warranty coverage period.

The DoD Guidance does provide for limitations placed on contractor obligation to repair or replace the failed items. Generally, consequential or incidental damages are not included as part of contractor obligation. Consequential damages are secondary losses that may take place as the result of an item failure. For example, the failure of a component might cause an aircraft to crash. The losses associated with the crash would be classed as consequential damages. Incidental damages include expenses that may indirectly result from item failure, including added operational, travel, and maintenance costs. To require the contractor to assume this responsibility would necessitate a considerable increase in its risks. The Government has traditionally operated as a self-insurer for such

losses. However, for one element -- transportation cost -- the general policy is to charge the warrantor.

2.2.5 Exclusions

The DoD Guidance recognizes that certain failures that are not the fault of the contractor and are completely beyond contractor control are normally excluded from warranty coverage. Examples include failures caused by fire, explosion, submersion, combat damage, and aircraft crash.

2.2.6 Unverified Failures

Some returned units will not exhibit failure when tested by the contractor. However, the contractor incurs costs in processing such units and might feel justified in asking that it be paid for processing each unverified failure. This agreement is not likely to motivate the contractor to minimize such occurrences through its design, built-in test equipment (BITE), maintenance manuals, and training procedures. Even so, it is probably unfair to have the contractor absorb all costs of unverified failures. A compromise is to reimburse the contractor for all such returns that exceed a stated percentage within a reporting period. Values between 20 and 30 percent have been suggested for avionics. The contractor can use such a rate as a bound for pricing.

2.2.7 Transportation

The DoD Guidance provides that the contractor pay the round-trip transportation cost for warranted units.

2.2.8 Warranty Pipeline Flow

There are several alternatives for controlling the flow of warranted units to and from the contractor:

- Repair and Return. Failed units are sent directly to the contractor. Upon repair, the unit is sent directly back to the using activity.

- Centralized Government Supply. Failed units are sent directly to the contractor. Repaired units are then sent to a Navy facility that performs normal supply functions for using activities.

- Bonded Storeroom. The contractor maintains a bonded storeroom for storage of repaired units. Upon failure of a unit at a base, the Navy notifies the contractor, which is required to ship a replacement from the storeroom within a specified time period (e.g., one working day). Meanwhile, the failed unit is shipped to the contractor for repair.

Whichever approach is adopted, a turnaround time requirement for in-plant repair may be included. This requirement obligates the contractor to process returned units (dock to dock) within a specified maximum or average number of days.

2.2.9 Warranty Data

The DoD Guidance provides that the contractor, at its own expense, prepare and furnish data and reports applicable to any correction required under the warranty, including revision and updating of affected data.

For an extensive form of warranty, the contractor should be required to maintain records and issue periodic reports necessary for assessing the effectiveness of the warranty, negotiating extensions, and making necessary contract price adjustments. Periodic reports should be required to monitor the contractor warranty performance. A semiannual warranty data report covering the previous six-month activity is recommended.

2.2.10 Government-Furnished Property

The DoD Guidance provides that "with respect to Government-furnished property the contractor guaranty shall extend only to proper installation so as not to degrade the Government-furnished property's performance and/or reliability, unless the contractor performs some modification or other works on such property, in which case the contractor's guaranty shall extend to such modification or other work."

2.2.11 Government Obligations

A warranty procurement may include some Government obligations. Examples include testing all suspected failures on applicable test sets prior to return to the contractor, using approved shipping containers, and furnishing failure-circumstance data.

2.2.12 Other Provisions

Other provisions that might be included within a warranty agreement are highlighted as follows:

- Warranty Labeling and Seals. The contractor should be required to install appropriate labeling and seals to indicate warranty coverage and minimize unauthorized tampering.

- Elapsed Time Indicators (ETIs). If operate hours are the basis for warranty coverage, a requirement for reliable and accurate ETIs should be included.

- Lost Unit Adjustment. A provision for adjusting the contract price for lost units, such as in transit, might be advisable for expensive units.

- Operate Hour Adjustment. If warranty coverage is on a calendar basis, it is advisable that there be provisions for adjusting the warranty price for deviations from a stipulated operate-hour factor used for pricing.

- Noncovered Failures. Normally, provision for contractor repair of all returns is required, including those failures not covered

under the warranty. This can be accomplished through a separate contract or through equitable adjustment in contract price for each such return.

- Repair Bill-Back. A provision may be included for the contractor to provide payment to the Government for performing warranty work.

2.3 MAJOR DATA ITEMS AND VARIABLES

This section identifies major data items and variables required to estimate total contractor costs for alternative warranty provisions.

Data items are used to characterize the costs of resources that the contractor will require for accomplishing its obligations under the warranty provisions in the contract. It is assumed that a contractor supplying the warranties will estimate all costs associated with these resources, and that these costs, augmented by profit and perhaps risk factors, will normally be included in the bid price. On the basis of the basic provisions for Navy procurements to meet the warranty requirements of Section 794 (summarized in Table 2-3), related major categories of warranty cost data items can be established. They are presented in Table 2-5.

The following subsections discuss the warranty cost data items in Table 2-5 and typical variables that influence the contractor resource requirements for each data item. These data items provide the basis for the assessment and development of warranty cost-estimating methodologies in Chapter Three.

2.3.1 Design and Manufacture Guarantee

This category includes the labor and material costs of redesign and remanufacture efforts that would be required for the weapon system and components to conform to specified performance requirements. These efforts may include (1) engineering analysis to determine causes of nonconforming units, (2) corrective engineering design and drawing changes, (3) modification of units, spare units, or spare parts as required; and (4) activities associated with retest and retrofit. Other variables include the warranty coverage period and the expected R&M performance characteristics (e.g., MTBF) for estimating the number of returned units.

2.3.2 Material and Workmanship Guarantee

This category includes labor and material costs of repair or replacement of equipment for defects in materials and workmanship. These efforts may include (1) failure analysis to troubleshoot failed part; (2) rework and repair; (3) repair parts and materials; and (3) final test and inspection and retrofit. Other variables include warranty coverage period and expected R&M performance.

TABLE 2-5

WARRANTY COST DATA ITEMS AND VARIABLES

Cost Data Items	Definition	Typical Cost Variables
Design and Manufacture Guarantee	Cost of design and manufacture modification so that system conforms to specified performance requirements	Engineering design labor Engineering drawings Parts and materials Warranty duration Expected MTBF
Material and Workmanship Guarantee	Cost of repair of defects in material and workmanship	Failure analysis Repair labor Parts and materials Warranty duration Expected MTBF
Warranty Management	Cost of administering warranty functions, including interface between warranty repair group, engineering design, R&M and quality groups, and higher management levels	Manager Warranty management plan factors
Facilities and Equipment	Cost of facilities and equipment to receive, test, repair, modify, store, and ship the warranty return	Primary repair facility Backup repair facility
Warranty Data	Cost of developing and maintaining a data system to meet warranty data collection and analysis requirements	Data plan Data records Data reports Data revisions and updates Computer
Transportation	Cost of handling and transporting to and from contractor repair facility	Shipping Receiving Inspecting Disassembling and reassembling Packing
Government-Furnished Property (GFP)	Cost of repairing defects in modification or installation of GFP	Repair labor Parts and materials
Consignment Spares	Cost of providing additional spare equipment on a consignment basis in the event the system reliability fails to meet stated levels during specified intervals	Pipeline unit spares
Warranty Price Adjustments	Cost of positive or negative adjustments to warranty price that depends on achieved warranty repair performance	Turnaround time penalty Unverified failure adjustment Operate-time adjustment Noncovered failure adjustment Warranty costs escalation adjustment Repair bill-back Exclusions adjustment Loss or damage in transit

2.3.3 Warranty Management

This category includes the labor costs for a designated manager, staffing, and procedures for managing the warranty. The necessary warranty functions to be performed include the liaison between the warranty repair group and design, reliability, quality-control groups, and higher management levels within the company.

2.3.4 Facilities and Equipment

This category includes the labor, computer, and material costs to procure and operate facilities and equipment to receive, test, repair, modify, store, and ship the warranty return. The contractor may be required to maintain a specified number of primary repair facilities. If only one prime repair facility is established, the contractor may be required to provide for backup repair facilities capable of being placed in operation within a stated time to protect against loss of repair services because of strikes and natural disasters. Test equipment may be required for failure verification and analysis.

2.3.5 Warranty Data

This category includes the labor, computer, and material costs of developing and maintaining a data system to meet warranty data collection and analysis requirements. These efforts may include the following:

- A data collection and analysis program that will accumulate, process, analyze, and report the information required under the warranty

- A semiannual warranty data report containing records relating to population size, configuration, and repair history

- An annual warranty effectiveness study containing the contractor's experiences and conclusions regarding the effectiveness of the warranty concept applied to the contract

In addition, the contractor will need to update any affected data, including drawings and technical documents, to reflect "redesign and manufacture" changes on failed items.

2.3.6 Transportation

This category includes the labor, material, and shipping costs of handling and transporting warranted items to and from the contractor repair facility.

2.3.7 Government-Furnished Property (GFP)

This category includes the labor and material costs of repairing defects in the modification or installation of GFP. These efforts would be similar to those for materials and workmanship guarantee (discussed in Section 2.3.2).

2.3.8 Consignment Spares

This category includes the material costs of providing additional spare equipment on a consignment basis in the event the system reliability fails to meet the stated levels during the warranty coverage. These spares are to relieve pipeline shortages that may develop as a result of low reliability in the weapon system and components.

2.3.9 Warranty Price Adjustments

This category includes a number of positive or negative adjustments that could affect total costs of warranty to the Government. These adjustment factors may or may not be "priced," depending on how a contractor views their fairness. The factors are described in the following subsections.

2.3.9.1 Turnaround Time Penalty

When a contractor is not in compliance with turnaround time requirements, some form of remedy may be required in the warranty provisions. Remedies that have been used include:

- Requiring the contractor to provide spare items at no cost to the Government on the basis of a specified formula

- Extending the time of warranty coverage for the entire population or for items not repaired in the specified period

- Establishing a monetary penalty on the basis of a specified formula

2.3.9.2 Unverified Failure Adjustment

It is expected that some warranty return units will "retest OK" when received at the contractor's repair facility. Because of the cost incurred by the contractor in processing these unverified failures, the warranty provisions normally specify a maximum number of units (either per calendar period or as a percent of total units returned) that the contractor is obligated to process without additional reimbursement. Values between 20 and 30 percent of the total units received are normally cited for electronic units that will be processed without reimbursement. When the maximum number of unverified failures is exceeded, the provisions will include a dollar-amount reimbursement to be paid to the contractor for handling and processing each unit returned above the maximum number allowed.

2.3.9.3 Operate-Time Adjustment

If warranty coverage is based on average operating hour per calendar period, it is advisable to provide for adjusting the warranty price for deviations from a stipulated operate-hour factor used for pricing. Both positive and negative adjustments may be authorized, but a minimum negative adjustment should be stated in recognition of the contractor's fixed warranty costs. To minimize making small changes, a no-adjustment zone should be established about the expected value (nominally ± 5 percent).

2.3.9.4 Noncovered Failure Adjustment

Repair of failures not covered under the warranty is generally performed under a service-type contract, e.g., time and materials. The number of out-of-warranty repairs is related to the extent of warranty exclusions such as failures due to catastrophic occurrences.

2.3.9.5 Warranty Costs Escalation Adjustment

Inflation adjustments may be made on the warranty price.

2.3.9.6 Repair Bill-Back

If provided for in the warranty provisions, the Navy may maintain its own repair facility or contract for repair services with independent repair facilities. The cost of each Navy warranty repair may be credited against future procurements or reimbursed for the work performed.

2.3.9.7 Loss or Damage in Transit

In the event a warranted item is lost or damaged to the extent that repair is not feasible, and the number of installed units is reduced by one, an economic adjustment is made for the remaining unused warranty protection. This adjustment may be monetary or in terms of additional warranty protection.

2.4 CONSIDERATIONS OF OTHER COST FACTORS

Based on the discussions thus far, it would seem that the contractor would price a warranty to reflect the required resources for performing its obligations under the warranty provisions. However, other factors in addition to the provisions may influence the eventual warranty price. The following subsections focus on such factors in the procurement, equipment, and operational aspects of the weapon system program and review the warranty price implications.

2.4.1 Procurement

The following factors within a weapon system procurement may influence the warranty price:

- Competition. Warranty price may reflect a competitive procurement environment that strongly motivates the contractor to estimate and price the warranty in the most cost-effective manner. A strong requirement to win may further motivate the contractor to bid a price lower than the expected warranty costs, especially if warranty cost is a source-selection factor.

- Sole Source. Warranty price may reflect a high warranty cost that is estimated by the contractor in the most conservative manner.

- Production Size. Warranty price may reflect the economy of a significantly large production award that influences the contractor

simply to "buy in" with a nominal warranty price lower than expected warranty costs. In effect, the contractor may be willing to risk the additional warranty costs against the expected profits. Or, it may realize an opportunity of an economically attractive production cost over a reasonable duration that will enable the design and implementation of cost-effective system performance during production and initial field deployment.

- Warranty Coverage Period. Warranty price may reflect uncertainties in a long-term warranty period that may force the contractor to price-in a large risk factor.

- Contractor System Experience. Warranty price may reflect the contractor's experience and confidence level in the design, development, testing, and field deployment of the equipment. If the contractor has system experience, the contractor's warranty price may be lower than if there are large uncertainties about the equipment design and performance.

- Contractor Warranty Experience. Warranty price may reflect the contractor's experiences and confidence with warranties in DoD procurements, including developed cost-analyzing tools and supporting warranty cost and performance data.

2.4.2 Equipment

The following factors regarding the equipment may influence the warranty price:

- Equipment Maturity. Warranty prices for additional procurements of equipment already in operation may reflect the achieved field performance and reliability characteristics of the equipment. The recently enacted Section 2403 will exclude the first 10 percent of production units from the essential-performance warranty requirements, i.e., a period for maturity growth.

- Technology Risk. Warranty price may reflect the added risks taken by the contractor in producing a new, high-risk technology or in speeding introduction of a new high-priority capability with concurrent development and production.

- Ruggedization. Warranty price may reflect the potential for indirect damage (e.g., hard handling, exposed environment) to the equipment that is not covered by exclusion provisions.

2.4.3 Operation

The following factors regarding the operational environment of the equipment may influence the warranty price:

- Operational Environment Known. Warranty price may reflect the contractor's picture of the expected conditions and usage of the equipment.

- Control of Unauthorized Maintenance. Warranty price may reflect the potential that the equipment may be serviced by untrained personnel, incorrect maintenance intervals, or improper materials.

- Field Testability. Warranty price may reflect the capabilities of test equipment and procedures in the field to verify a failure occurrence.

2.5 SUMMARY

This chapter provides the basis necessary for assessing methodologies that could lead to the establishment of uniform procedures for estimating the warranty price/cost for Navy weapon system procurements. This basis includes:

- Identification and review of warranty provisions to determine characteristics of contractor obligations in providing warranties that meet the intent of Section 794.

- Identification of significant cost factors, which are associated with the contractor's resources for accomplishing its warranty obligations, that should influence warranty price.

The influence of many of the cost factors on warranty price can be modeled, and data may be available for obtaining parametric estimates. However, there are a number of other factors less amenable to modeling for price/cost-estimation purposes, such as those related to a competitor's desire to win the contract (e.g., buy-in) or a competitor's risk perceptions based on its experience. Therefore, as with many cost-estimation procedures, there may be a significant element of variability that cannot easily be accounted, especially without a large data base.

CHAPTER THREE

EVALUATION OF WARRANTY COST-ESTIMATION METHODOLOGIES

The purpose of this chapter is to identify and assess methodologies that show promise as uniform Navy procedures for estimating the price of warranty requirements of Section 794.

In 1980 the University of Southern California conducted a study for the Office of Navy Research (Ref. 8) of models that have been developed for analysis of warranty costs. It was concluded that warranty costs for the contractor depend fundamentally on two elements: structure of the warranty (i.e., provisions) and life distribution of the item being sold under warranty. It was further concluded that warranty cost models are basically economical and statistical in nature: economic in that they deal with warranty costs, and statistical in that costs are a function of the life distribution of the item. In the ensuing discussions, it will be assumed that warranty cost-estimation methodologies reflect the warranty structure, at least implicitly, and are a function of some characteristics of the life distribution.

Section 3.1 reviews the results of a survey in which ARINC Research investigated models available to DoD for estimating warranty price; Section 3.2 assesses the potential of an Air Force RIW pricing model; Section 3.3 discusses other warranty pricing methodologies that are available or could be developed; and Section 3.4 compares the methodologies reviewed.

3.1 WARRANTY COSTING SURVEY

Currently, no formal warranty cost-estimation model is being used in Navy procurements. This finding is based on surveys of and discussions with key NAVSEA, NAVAIR, and NAVELEX offices engaged in warranty economics and management. Generally, costs for warranty requirements of Section 794 are estimated on an ad hoc basis in Navy program offices with no formal quantification of the cost estimates and risk areas.

Although the surveys pertained to the Navy warranty cost-estimation process, the same situations are true for other DoD procurements. In discussions with the Air Force Product Performance Agreement Center and other cognizant DoD offices, we have found that there is no standard approach to "pricing" the warranty requirements of Section 794. Currently, it appears that MAT-01F4 is one of the leading DoD activities preparing such uniform warranty cost-estimation procedures for use in weapon system procurements.

Although no warranty cost-estimation model exists for dealing with Section 794, several models have been identified for analyzing the life-cycle cost (LCC) associated with a reliability improvement warranty (RIW). The Air Force has a model called LCC-2, which includes provisions for comparing RIW to organic maintenance support (Ref. 9) but does not contain RIW price-estimating procedures. In 1975 the Air Force also developed a comprehensive warranty LCC model for RIW (Ref. 10). The model is computerized, publicly available, and fully documented. It includes an RIW pricing model that can form the basis for developing a uniform approach to estimating warranty price/cost associated with meeting the warranty requirements of Section 794. This RIW pricing model is discussed in Section 3.2.

We also examined a simplified pricing model for RIW that was presented by associates of The Analytic Sciences Corporation (TASC) at the 1977 Annual Reliability and Maintainability Symposium (Ref. 11). The model assumes that the contractor is operating in a competitive environment and is unwilling to "buy in." The price would, therefore, reflect the total expected cost associated with performance of RIW obligations plus a reasonable profit. The model is presented in the following form:

$$W = P + C_W + \frac{Q_T U t_w}{MTBF_a} C_r + I(MTBF_a) + D_t$$

where

W = fixed price paid to the contractor for the warranty

P = profit

C_W = fixed costs to the contractor associated with the warranty

Q_T = total number of systems to be delivered

U = usage rate in operating time per calendar time

t_w = duration of warranty period

$MTBF_a$ = achieved MTBF (average over the RIW period)

C_r = cost to the contractor per unit repair

$I(MTBF_a)$ = cost of improvement actions to achieve $MTBF_a$

D_t = damages for not meeting the turnaround time requirement

This TASC model and the Air Force RIW pricing model (Ref. 10) are similar in format and cost elements addressed. However, this report will continue to refer to the Air Force RIW pricing model on the basis of the availability of the model equations, algorithms, procedures, and development background in Air Force documentation.

In addition, two other warranty pricing methods have been identified. Both are more simplistic than the RIW pricing model, but they could be advantageous in warranty cost estimating under certain conditions. The methods are:

- Warranty price ratio - warranty price expressed as a percent of unit production price

- Warranty cost-estimating relationships - warranty price equation developed as a cost-estimating relationship (CER), using historical data

These methods are discussed in Section 3.3.

3.2 POTENTIAL OF AIR FORCE RIW PRICING MODEL

This section reviews and assesses the Air Force RIW pricing model (Ref. 10) for potential as a uniform procedure for estimating Section 794 warranty price/cost in the procurement of Navy weapon systems.

3.2.1 Model Overview

The RIW pricing model is described by purpose, cost factors, computational procedure, and output in the following subsections.

3.2.1.1 Purpose

The model was designed to provide an estimate of warranty price before bid prices are received, or to provide an independent assessment of warranty price.

The model is essentially a bottom-up approach to warranty cost estimation. The cost categories and elements of the model are identified and summed in an accounting fashion. Warranty price calculations would use the generic form shown in Table 3-1. Table 3-2 describes the major cost categories. Reference 10 is suggested for review of the applicable equations, algorithms, and guidance for using a computer program developed to exercise the model.

3.2.1.2 Cost Factors

The RIW pricing model is sensitive to a number of cost factors as determined by the warranty coverage selected. Examples of such factors are as follows for each of the major cost categories in the model:

- Fixed direct costs

  -- Special facilities

  -- Equipment

In words, this CER could be seen as:

warranty cost % = (baseline percentage)

$+ (\text{coefficient}_1) \times$ (months discovery of latent defects)

$+ (\text{coefficient}_2) \times$ (months coverage period of operational defects)

$+ (\text{coefficient}_3) \times$ (contractor repair indicator)

$+ (\text{coefficient}_4) \times$ (Government repair indicator)

$+ (\text{coefficient}_5) \times$ (special test complexity measure)

$+ (\text{coefficient}_6) \times$ (months coverage of operational performance)

$+ (\text{coefficient}_7) \times$ (cost adjustment indicator)

$+ (\text{coefficient}_8) \times$ (redesign indicator)

In these CERs, the coefficients would be determined through statistical regression analysis of data, but they could be related to physical quantities such as MTBF or average unit repair cost.

4.2.3 Bottom-Up Accounting Model

The third methodology recommended for warranty price/cost estimation is the use of a bottom-up accounting model. The procedures followed in applying this methodology are to identify all warranty/guarantee cost elements and, in an accounting fashion, estimate the factors involved and sum them to attain a total cost for the contractor. Essentially, the total cost is estimated by the sum of all partial costs expected during the period of the warranty. Estimation of the partial costs can include rules-of-thumb and CERs as well as direct accounting procedures. Construction of a bottom-up accounting model depends on a detailed examination of the events that could occur during the warranty period, how often they are expected to occur, and what their cost would be.

Chapter Three of this report describes our investigation of warranty cost models and our assessment of the current availability of such models. We concluded that no formal warranty cost-estimation model is currently being used in Navy procurements. Furthermore, we concluded that the Air Force RIW pricing model is the only available model that contains detailed cost-estimating procedures concerning warranty price. Our assessment indicated that the RIW pricing model includes procedures to estimate cost data items for material and workmanship guarantee, warranty management, facilities and equipment, warranty data, and transportation. The model requires enhancement to incorporate procedures for estimating the costs of

would be described by one complete path of the hierarchy from level 1 to level 4, including the intermediate choices. A warranty could have more than one provision; for example, a latent defect discovery period would be typical of almost all warranties, and additional provisions could be common. Each provision would add an amount to the warranty cost.

A strategy for developing warranty CERs, therefore, could be based on the desired level of the warranty provision hierarchy. The CER equation typically takes the linear, multivariate form:

$$\$ = a_o + a_1x_1 + a_2x_2 + a_3x_3 \ldots + a_nx_n$$

where

$ = warranty cost per unit acquisition cost per year

a_o = constant

a_i = coefficient of i^{th} cost variable

x_i = i^{th} cost variable

At the simplest level, a level 1 CER for warranty cost estimation by control method could be described by three cost variables: a baseline cost percentage, a design and manufacture control indicator, and a materials and workmanship control indicator. The CER would be of the form:

$$\$ = a_o + a_1x_1 + a_2x_2$$

= (baseline percentage)

+ (design control percentage) × (design control indicator)

+ (materials control percentage) × (materials control indicator)

Values of the indicators would be either 1 or 0, depending on whether the provision was or was not in effect.

The most complete and complex CER at the fourth level of corrective methods would incorporate variables from the three higher levels as well. Mathematically, the form could be expressed as:

$$\$ = a_o + \sum_{i=1}^{8} a_i x_i$$

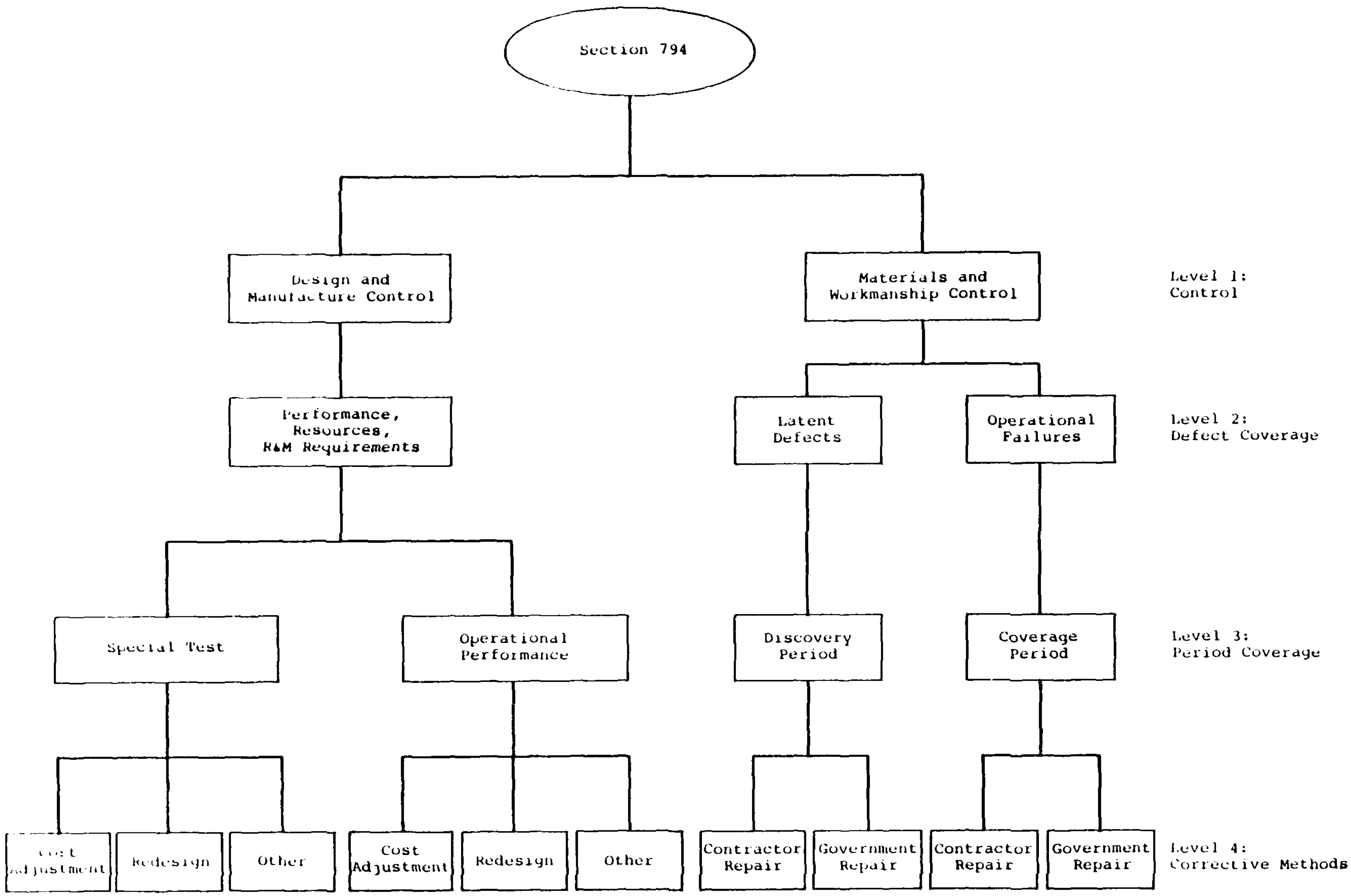

FIGURE 4-3

WARRANTY/GUARANTEE PROVISION HIERARCHY

warranties would have the same advantages and disadvantages based on generalities, but with a firm statistical foundation of past cost histories. Data from a number of warranty provisions are required to formulate useful CERs.

While warranty cost could be estimated through a CER based on the size and weight of the system purchased, other, more critical data variables should be taken into account. A first-order CER could be that warranty cost is a percentage of unit acquisition cost, as in the rule-of-thumb ratio methodology. A complete CER would go into more detail to relate cost to other data items and determine the statistical coefficients. Table 2-5 lists pertinent warranty cost data items and variables; the warranty cost data collection form, presented in the Appendix, is an extensive list of factors pertinent to warranty price/cost. The most important factors affecting warranty price appear logically to be the specific details related to the provisions of the warranty, such as the duration of the coverage, the corrective actions required, and the stringency of the requirements. In addition, the failure statistics of the system are an obvious cost driver. Table 2-3 lists 12 categories of major warranty/guarantee provisions upon which CERs could be developed.

The following equation, with hypothetical numerical values, is a simplified example that illustrates the concept of a CER for warranty cost that could be derived from data:

$$\left(\frac{\text{warranty cost per year}}{\text{unit acquisition cost}}\right) = 4\% \\ + 0.2\% \times (\text{months of discovery period}) \\ - 0.1\% \times (\text{years equipment has been fielded})$$

Here, months of discovery period refers to the number of months covered by the warranty for discovery of latent defects; years equipment has been fielded refers to the number of years of experience the contractor has with the equipment in actual field operation. The percentages and factors are for illustration only.

One recommended methodology for developing CERs to a desired level of detail could be patterned after the warranty/guarantee provision hierarchy illustrated in Figure 4-3. The figure categorizes, by four levels of detail, warranty provisions satisfying the intent of Section 794. The first level describes the nature and extent of control provided for by the warranty -- either control of the design and manufacture of the item itself or more restricted control over materials and workmanship. At the second level, the nature of the coverage of defects is detailed. The warranty provisions may impose strict performance requirements, may cover only latent defects, or may also cover operational failures. The third level identifies the type of coverage period, the time frame, and the way in which defects will be detected. At the fourth level, the breakdown describes what corrective measures are to be taken and what party is responsible for the repairs. From Figure 4-3, therefore, a warranty provision

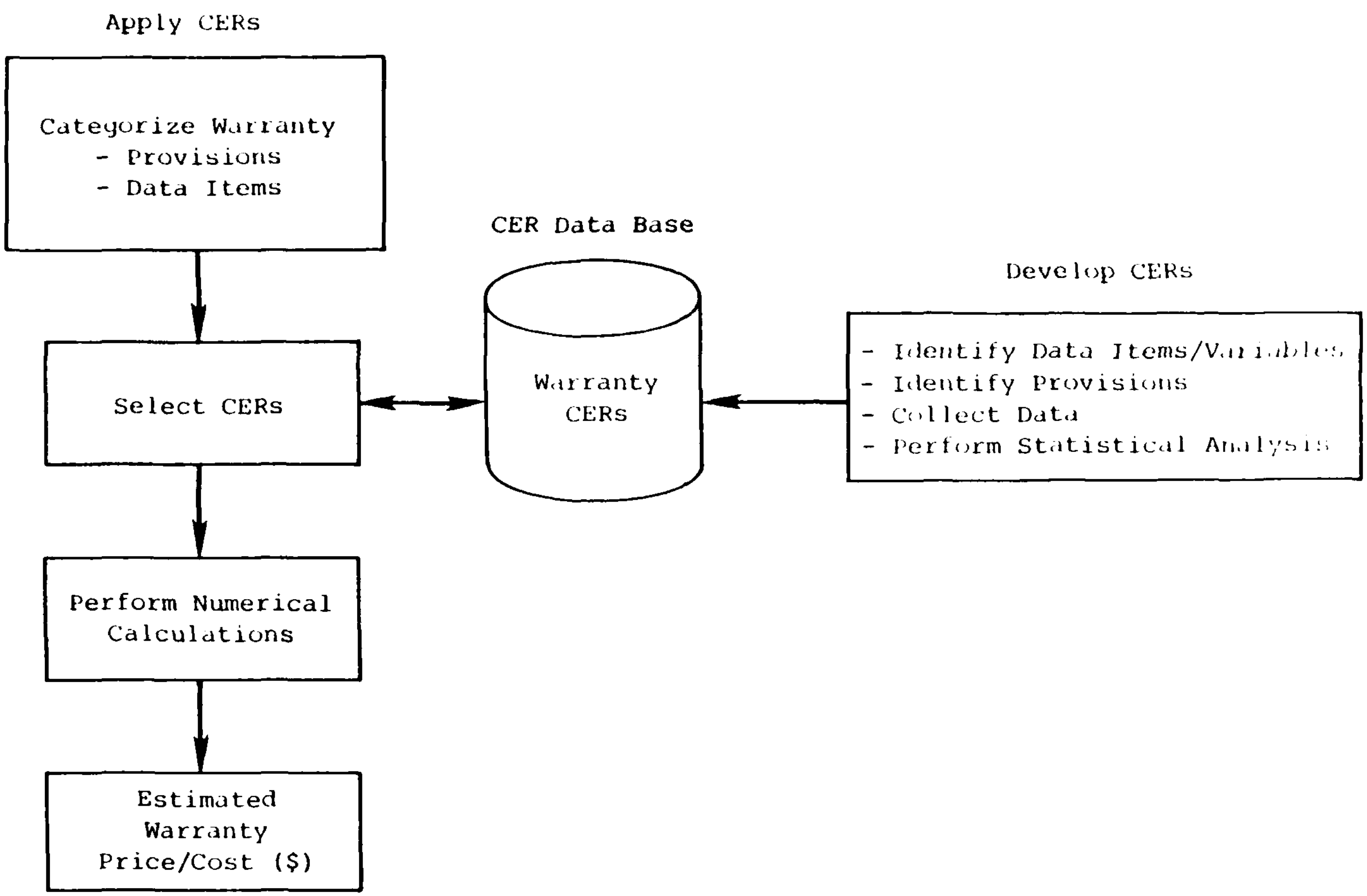

FIGURE 4-2

APPLICATIONS OF WARRANTY CERs

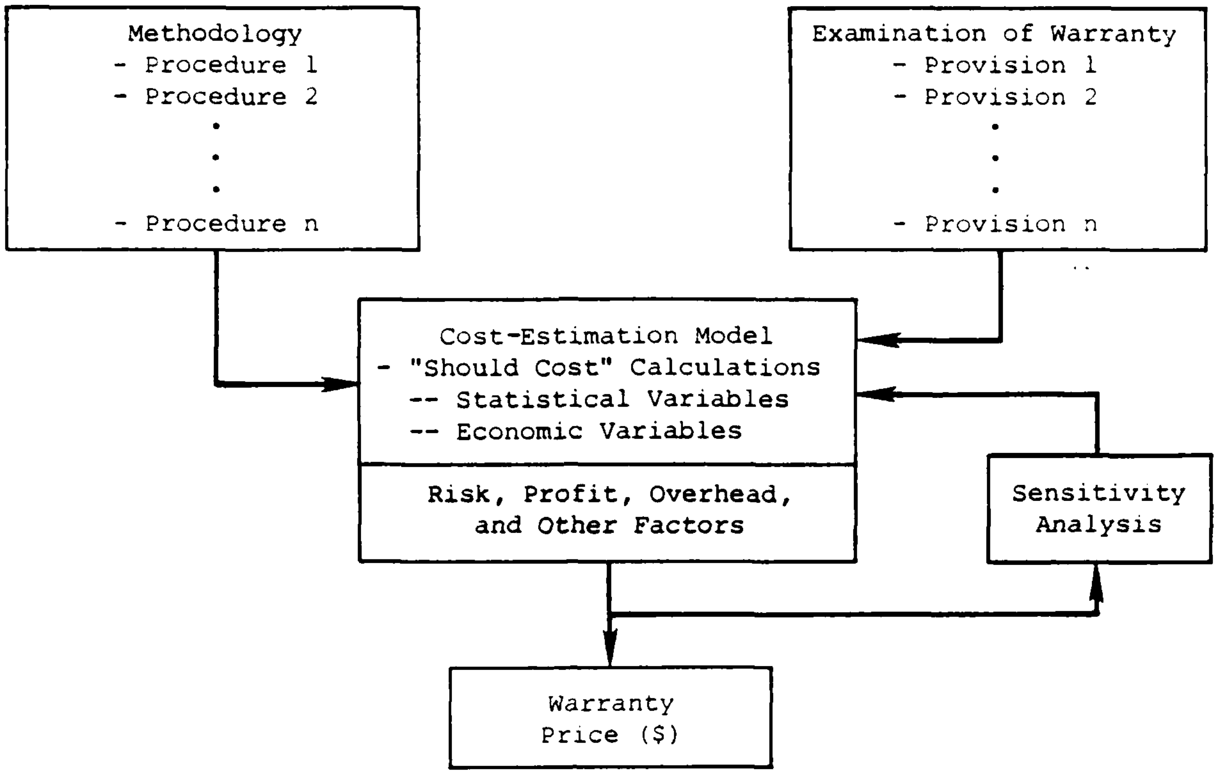

FIGURE 4-1

USE OF WARRANTY COST-ESTIMATION METHODOLOGIES

contracts were not required by law to contain warranty provisions until 14 March 1984. However, several ideas and concepts have been in existence for years, and their application now is particularly appropriate. The Air Force RIW pricing model was assessed in Chapter Three as a candidate for warranty cost estimation. In fact, it is the only publicly available cost model addressing warranty price in depth that we were able to identify. Without attempting to derive all the cost equations within the limited scope of this effort, we will outline the methodology suggested by this model. In addition, standard parametric cost-estimation techniques, such as top-level basic estimators and statistically derived cost-estimating relationships (CERs), can be applied to warranty price.

On the basis of our research and analysis, we recommend three potentially effective warranty cost-estimation methodologies for Navy programs: (1) rule-of-thumb ratio, (2) warranty cost-estimating relationships (CERs), and (3) bottom-up accounting model. In this context, the term methodology, or model, refers to a general approach and could consist of many steps that are referred to as procedures. The three methodologies vary greatly in the amount of detail they provide and the amount of data that would be required to make the best use of them. Table 4-1 summarizes the three methodologies. The following subsections describe these methods in detail.

CHAPTER FOUR

WARRANTY COST-ESTIMATION METHODOLOGIES

4.1 INTRODUCTION

The preceding chapters have listed and catalogued warranty provisions, identified variables and cost drivers, and provided assessments of methodologies for estimating the cost of warranty provisions in accordance with Section 794 of the 1984 DoD Appropriation Act. In this chapter, the most promising procedures are recommended for warranty cost estimation for Navy programs. It is intended that the recommendations will form a basis for establishing uniform Navy procedures and guidelines. The next step will be to develop these procedures fully and then attempt to quantify and calibrate the models on the basis of historical data.

To estimate warranty price, we must assume that the price reflects the cost to the contractor of providing this service. In this sense, the methodologies estimate what the warranty "should cost," or what could be construed to be "fair and reasonable" costs. Because the requirement is recent, and because issues other than expected cost could be factors, the prices now being quoted may not reflect accurately the actual warranty cost. Such issues as risk evaluation, profit margin, competitive pressure, and desire to win may influence the price now and in the future. To the extent possible, this study will concentrate on estimation of what we believe the warranty "should cost."

Use of the warranty cost-estimation methodologies is illustrated in Figure 4-1. An appropriate methodology is chosen and the warranty is carefully examined for all provisions and clauses. This information is used in a cost model to derive warranty price. The cost model could be as simple or as complicated as the data, time, and resources justify. An analysis of sensitivity to the key cost driver variables identified in Chapter Two of this report may be appropriate.

4.2 THREE COST-ESTIMATION METHODOLOGIES

In the course of our research for this effort, we were unable to identify any standard DoD warranty cost-estimation models. This is not surprising, since the subject of DoD-wide warranty application did not receive widespread attention until the 1984 Appropriation Act, and DoD

As is the case with the WPR approach, as more experience accumulates with Section 794 warranties/guarantees, collecting applicable data for CER development becomes a viable approach.

3.4 SUMMARY

Table 3-4 summarizes the three warranty price/cost-estimation methodologies with respect to a number of different factors. The entries are subjective assessments based on our experience in warranty/guarantee and costing and should not be considered absolute. For example, the difficulty in developing a WPR is rated low to moderate. However, it must be recognized that developing a reasonably effective WPR predictor may not be possible. Perhaps no rationally acceptable basis for categorizing procurements can be found, even though there is a large variation in percentages. Thus, while the mechanisms of developing the ratios are simple, the underlying concept may not be valid enough to permit development of good estimators.

TABLE 3-4

SUMMARY OF WARRANTY COST-ESTIMATION METHODOLOGIES

Factors	Air Force RIW Pricing Model	Warranty Price Ratio	Warranty Cost-Estimating Relationships
Form	Computer Program	Average ratio by category	Equation(s)
Development Basis	Accounting/logic basis	Average historical data	Statistical analysis of historical data
Development Difficulty	Moderate	Low to moderate	Moderate to high
Ease of Application	Moderately difficult	Very easy	Easy
Accuracy Potential	Moderate to high	Least accurate	Moderate
Trade-Off Potential	Good	Very limited	Somewhat limited
Expandability	Moderate	Limited	Moderate

3.2.2.5 Potential

The RIW pricing model is a type of warranty cost estimation that can be useful in detailed trade-off analysis to relate warranty benefits to budgets or to contractor cost proposals. The model can easily incorporate the effects of changing system performance parameters and warranty/guarantee provisions.

3.3 OTHER WARRANTY PRICING METHODOLOGIES

Because the RIW model discussed in Section 3.2 is an engineering and accounting model, the data required to use the model are frequently not available during early stages of system development. However, a need still exists for methods to estimate warranty price. This can be accomplished by parametric models. Parametric models may also be used to check the results of engineering and accounting models, or to offer a quick estimate with little resource expenditure. Two such models are presented in this section: warranty price ratio and warranty cost-estimating relationships.

3.3.1 Warranty Price Ratio (WPR)

A common way of expressing the price of a warranty in a normalized form is in terms of percent of unit production cost per year of warranty. For example, if a $20,000 unit is warranted for three years at a warranty price of $1,200 per unit, the warranty price ratio is:

$$WPR = \frac{1,200}{20,000 \times 3} \times 100\% = 2\%$$

As Section 794 is implemented, there will be a relatively large increase in the number of contracts for which WPRs can be calculated.

Analysis of these WPRs in conjunction with price-influencing variables may reveal categories for grouping procurements to allow for "rule of thumb" estimates based on a WPR measure. This type of warranty cost estimation can be useful as a first-cut approach to establishing budgets and evaluating contractor cost proposals.

3.3.2 Warranty Cost-Estimating Relationships (WCER)

This approach is based on the assumption that a statistical relationship can be established between warranty price or cost and price-influencing variables. For example, one can hypothesize that warranty price will increase as the expected equipment operational failure rate increases. Using historical data with operational failure rate as one of the candidate prediction variables, techniques such as multiple regression analysis can be employed to determine the significance and form of the relationship.

work required into individual tasks until it becomes clear what steps and resources are necessary for completing each task.

3.2.2.4 Suitability to Navy Programs

The RIW pricing model has potential applications for weapon systems procured by the Navy if reliability performance guarantees are to be furnished. However, since warranty requirements of Section 794 may require equipment performance warranties, additional model equations and procedures must be developed.

Table 3-3 indicates general cost areas where the RIW pricing model relates to those major warranty cost data items (described in Chapter Two) required to estimate total contractor costs for alternative warranty/ guarantee provisions of Section 794. The model will require further development in the following general cost areas: design and manufacture guarantee, GFP, consignment spares, and warranty price adjustments.

TABLE 3-3

RIW PRICING MODEL RELATIONSHIP WITH SECTION 794

Section 794 Warranty Cost Data Items	RIW Pricing Model
Design and Manufacture Guarantee	
Material and Workmanship Guarantee	X
Warranty Management	X
Facilities and Equipment	X
Warranty Data	X
Transportation	X
Government-Furnished Property (GFP)	
Consignment Spares	
Warranty Price Adjustments	

3.2.1.4 Output

The fundamental output of the model is the estimate of the price paid to the contractor for providing the RIW.

3.2.2 Model Assessment

With respect to Navy implementation of Section 794, the following subsections examine the RIW pricing model for logic of approach, accessibility of required data, complexity, suitability to Navy programs, and potential for generalization to uniform procedures.

3.2.2.1 Logic of Approach

As previously discussed, the warranty price depends on two elements: the structure of the warranty in terms of the provisions, and the life distribution of the warranted item. A warranty cost-estimation model should, therefore, reflect some aspects of these two elements.

The RIW pricing model was designed to reflect the contractor commitments to perform depot-type repair services during a specified coverage period. The economic and statistical factors in the major cost categories of the model are listed in Section 3.2.1.2. The economic factors (e.g., parts and material costs, shipping costs) deal with the costs of the contractor commitments that are established by the warranty provisions or structure. The statistical factors (e.g., MTBF, operating time) relate the costs to some function of the characteristics of the life distribution of the warranted item.

The logic of the RIW pricing model would be appropriate to cost estimation of warranties requirements in Section 794. Warranty cost estimates would focus on the structure of the warranty and life distribution of the warranted item. The model is capable of assuming an average rate of failure over the warranty period, as well as changes in failure rate. Reliability growth functions are presented in Reference 10.

3.2.2.2 Accessibility of Required Data

A good warranty cost data base is required for the model cost factors (Section 3.2.1.2). A better data base will be available if the system has been fielded and operational performance characteristics are used. For new procurements, the data base will have to be based on engineering and cost analyses, specifications, and test data.

3.2.2.3 Complexity

The RIW pricing model, as shown in Table 3-1, is an engineering and accounting model. It represents a deterministic bottom-up approach in which the cost categories and elements are identified and combined in the appropriate mathematical manner. Specific equations have been developed for treating each of the cost variables (Ref. 10). The approach provides moderate flexibility for selected warranty structures by breaking down the

- Risk

- Profit

For a contractor that has been associated with repair activities, these categories are not considered unusual except for risk, which provides for the uncertainties associated with the warranty commitment.

An important uncertainty that influences all factors is the long-term commitment. A contractor may be able to estimate the costs of repair parts over the next year but may be uncertain about such costs for the third or fourth year of the warranty, especially in a fluctuating economy. Other unusual risk factors are MTBF estimation, the number of good units returned, commitments on turnaround time, MTBF guarantees, and other potential liabilities included in the warranty terms and conditions.

Certainly, the risk elements could make warranty pricing a hazardous venture for equipments with new technology or for contractors with limited experience. For this reason, it is important that the Navy conduct an independent cost assessment to evaluate the realism of the warranty price and to determine whether such a price is consistent with stated program objectives or contractor-proposed values. Such an assessment will place the Navy in a stronger position for a warranty decision or price negotiation. If, for example, an independent cost assessment with appropriate sensitivity analysis shows that the contractor's competitive warranty price is very low, there is an area for concern over whether satisfactory warranty performance will be provided later. If the Navy will eventually have to renegotiate the warranty price to "bail out" the contractor or else be forced to make an early, unplanned transition to organic maintenance, total life-cycle costs may become significantly higher than anticipated and operational readiness may be reduced.

It is possible for the warranty price to be inconsistent with a contractor-stated MTBF, which may be much higher than expected. There is also concern that the actual equipment MTBF may be lower than advertised, causing serious problems in sparing, logistics flow, and readiness.

As difficult as initial RIW pricing may be for the contractor, an independent pricing exercise performed by the Navy will be that much more difficult until a good warranty-cost data base is established. The method described in Table 3-1 is quite simplified, but it includes the major factors that, when varied over a suitable range of input data values, should provide a reasonable range of expected warranty costs. For estimating warranty price to aid in negotiating a warranty extension, a much better data base will be available from contractor and Navy data records obtained during the initial warranty. However, timely collection and analysis of such data should be planned to utilize fully the information provided during the initial warranty period.

- Cost per repair and return variables
  - -- Operating hours
  - -- MTBF
  - -- Good-return rate
  - -- Repair labor hours
  - -- Contractor repair labor rate
  - -- Parts and material cost per repair
  - -- Handling and shipping costs
  - -- Labor hours to process nonfailed unit
  - -- Repair learning rate
- Warranty data and administration costs
  - -- Total repair cost
  - -- Total cost for good return
  - -- Percentage of total costs for administration and data analysis
- Other yearly costs
  - -- Warranty data report costs
  - -- Test equipment support costs
  - -- Technician training costs
  - -- Bonded storeroom costs
  - -- Module sparing costs
  - -- Other categories

3.2.1.3 Computational Procedure

The following major cost elements are applicable to the contractor's pricing of an RIW:

- Fixed costs - facilities and equipment
- Warranty repair costs
- Warranty administration and data costs

TABLE 3-1

RIW PRICE EQUATION

RIW Price = [(Fixed Direct Costs) + (Other Yearly Costs) (Number of Years) (Discount Factor) + (Cost per Repair) (Expected Number of Repairs) (Discount Factor) + (Cost per Good Return) (Expected Number of Good Returns) (Discount Factor) + (Warranty Data and Administration Costs) (Discount Factor)] × (Risk Factor) (Profit Factor)

TABLE 3-2

DESCRIPTION OF MODEL COST CATEGORIES

Cost Category	Description
Fixed Direct Costs	Costs of special facilities and equipment that will be required to implement the warranty.
Other Yearly Costs	Recurring costs in other categories such as warranty data report costs, test equipment support costs, technician training costs, bonded storeroom costs, and module sparing costs.
Cost per Return	Average cost of processing a unit returned for a warranty repair, including the following costs: initial inspection, failure verification, repair scheduling, troubleshooting, rework and repair, repair parts, final test and inspection, and shipping and handling. Cost of processing a good return would normally entail inspection, failure verification, and shipping.
Warranty Data and Administration Costs	Costs of administering the warranty and of the activities associated with data collection and analysis.

design and manufacture guarantee, Government-furnished property (GFP), consignment spares, and warranty price adjustments. Of these enhancements, the addition of a capability to estimate redesign costs is a first priority.

The RIW pricing model was presented in Chapter Three. It is a bottom-up accounting model that estimates costs based on a logical, engineering approach designed to include all incurred costs and calculate their sum. The RIW pricing model uses economic variables such as facilities costs, and statistical variables such as MTBF and expected number of good returns. As it currently exists, the model operates with 30 variables, 11 of which are required input variables. The complete model description of equations and terms may be found in Reference 10.

The general form of the equation for RIW price is as follows:

$$\$RIW = (\$repair + \$good\ returns + \$admin + \$yearly + \$fixed) \times (risk) \times (profit)$$

The terms in the first set of parentheses are calculated in an accounting method through the general procedures described in the following paragraphs.

Repair costs are estimated as:

$$\begin{aligned}\$repair &= (\text{cost per repair}) \times (\text{number of repairs}) \\ &= \left[\left(\frac{\text{cost}}{\text{hour}}\right) \times \left(\frac{\text{hours}}{\text{repair}}\right)\right] \times \left(\frac{\text{operating hours}}{\text{expected hours per failure}}\right) \\ &\quad + (\$material) + (\$shipping)\end{aligned}$$

To illustrate the depth of the RIW pricing model in evaluating factors that influence warranty price, the following calculaton of expected number of repairs is presented. The expected number of repairs necessary over the time period of the warranty is, of course, dependent on the failure statistics of the system. With the common assumption that the occurrence of failures can be modeled by a Poisson process (that is, that the first-order interarrival times are independent exponential random variables), then the expected number of failures in operating time T is given by:

$$\begin{aligned}\text{expected number of failures in T} &= \sum_{k=o}^{\infty} \frac{(\lambda T)^k}{k!} e^{-\lambda T} \\ &= \lambda T \\ &= T/(MTBF)\end{aligned}$$

where

λ = average arrival rate of failures (failures per hour)

MTBF = mean time between failures (hours per failure) = $1/\lambda$

Therefore, the expected number of repairs is estimated by the quotient of the number of operating hours under warranty divided by the MTBF. The expected repair time in number of hours per repair can be calculated with inclusion of learning term effects when appropriate.

The cost of returned items for which no failure can be found (good returns) is:

$$\text{\$good returns} = (\text{good return rate}) \times \left(\frac{\text{operating hours}}{\text{MTBF }(1 - \text{good return rate})}\right) \times \left(\frac{\text{hours}}{\text{repair}}\right) + (\text{\$shipping})$$

Warranty management costs are estimated as a percentage of the total costs:

$$\text{\$admin} = (\text{management \%}) \times (\text{total costs})$$

Yearly operating costs are summed over the total number of years of the warranty's lifetime:

$$\text{\$yearly} = (\text{\$warranty data}) + (\text{\$test equipment support}) + (\text{\$technical training}) + (\text{\$storeroom}) + (\text{\$spares})$$

Facility and equipment costs are summed to give the total fixed expenses:

$$\text{\$fixed} = (\text{\$facilities}) + (\text{\$equipment implementation})$$

A bottom-up warranty cost accounting methodology is recommended for warranty cost estimation in situations where the warranty is fairly well defined and sufficient time and resources are available. This methodology is the most time-consuming but has the most potential for detail and accuracy. The RIW pricing model is the only comprehensive, detailed accounting warranty model currently available, and it can be augmented to include new warranty provisions. It is appropriate for most aspects of warranty cost estimation, particularly for independent cost assessments.

4.3 SENSITIVITY AND RISK ANALYSIS

An important part of the cost-estimation methodology is the performance of a sensitivity analysis to determine how the final cost estimate varies with changes in the variables in the equation. For example, a key cost driver will be the expected number of failures in the warranty period,

usually determined from the MTBF or an equivalent statistic. In fact, upper and lower values for MTBF with a specified confidence level are often provided or can be estimated. These values should be substituted in the cost-estimation equations to determine a warranty cost range as MTBF varies, because field variations in MTBF are a common experience. Similarly, ranges should be computed for other important variables. For the rule-of-thumb methodology, there is only one variable -- unit acquisition cost -- and the estimate is a straight percentage of that cost.

The risk factor is a single parameter incorporating the risk costs associated with the warranty. A contractor, in actually pricing the warranty, is expected to consider essentially all of the terms in the warranty-price equation. Assume that, as a result of previous field data on similar equipment, reliability predictions, and reliability demonstration results, the contractor estimates that average MTBF over the warranty period will range between 400 and 500 hours. The actual value the contractor inserts in its pricing formula will reflect the trade-offs it makes between risk aversion and desire for award in a competitive climate. If the contractor is highly risk-conscious, it will select a low MTBF within the probable range, in hopes that it will be in a favorable competitive range. A contractor not adverse to risk-taking may elect to use the higher MTBF value to increase the chances for an award.

Other considerations in determining how much risk is involved or how to price the risk factor include user objectives, contractor price, administrative difficulty, enforceability, contractor reliability improvement motivation, time period, type of services, and logistics management difficulty.

Risk analysis involves both internal and external risk to the contractor. Decrease in risk through improvement in reliability comes from such areas as the following:

- Assembly process and techniques
- Workmanship and handling
- Human factors engineering
- Environmental stress screening
- Consideration of the consequences of a given failure
- Use
- Reliability of components

In an interview with staff members of the Defense System Management College (DSMC), ARINC Research identified several ways of handling risk. They are presented in Table 4-2 for consideration of the best approach.

TABLE 4-2

WAYS OF HANDLING RISK

Method	Definition
Risk Avoidance	Not being subjected to risk by refusing to get in a position to allow failure (e.g., using a different type of contract, taking a different component); choice of alternatives
Risk Control	Lowering the probability of a situation or the consequence of its happening (having backups; budgeting for a portion of fix and retest)
Risk Assumption	Accepting the risk (ignoring potential consequences; self-insurance)
Risk Transfer	Using insurance companies, incentive clauses in contracts, warranties
Knowledge and Research	Examining the situation and developing options, preparing plans to transfer or avoid, and examining contract techniques and strategies

The approach used in the RIW pricing model is to compute one overall risk factor. Rather than consider risk values for each of the cost elements, the contractor may price the warranty by using best estimates and then adjusting total warranty by a risk factor (RSF) or, equivalently, using a higher profit factor. The risk factor has the following form if the warranty period is T years:

$$RSF = (1 + RSK)^T$$

where

RSK = risk factor for a one-year period, expressed as a decimal

As the warranty period increases, so does the risk factor for all RSK > 0. The risk factor has a compound-interest form, so that the risk per year of warranty increases as the warranty period increases, which is probably more realistic than a simple-interest form.

The profit factor in the RIW model for warranty price represents the usual fee charged in Government contracts for profit. Note that the profit factor has been separated from the risk factor in the RIW model. In actual practice, the contractor may combine the two by applying a higher profit factor to its estimated loaded warranty costs than is used for other cost items. For example, a company often applies a higher fee percentage for a fixed-price contract than for a cost-reimbursement type contract, because the former is more risky. We have kept the two separate simply to distinguish the underlying forces that affect price and to simplify sensitivity analyses.

4.4 SUMMARY

Three methodologies have been presented in this chapter as recommended candidates for performing warranty cost estimation for Navy programs. The methodologies and their respective advantages and disadvantages are summarized in Table 4-3.

TABLE 4-3

ADVANTAGES AND DISADVANTAGES OF WARRANTY COST-ESTIMATION METHODOLOGIES

Methodology	Advantages	Disadvantages
Rule-of-Thumb Ratio	Simplicity Quick answer for cost order of magnitude Minimum data requirements	"Ballpark" estimate only Lack of detail No differentiation
Warranty CERs	Easy to use once developed More detail than rule-of-thumb Identification of cost drivers Firm statistical basis	Extensive data requirements Costly to develop May require changes with time Only as good as similarity to past
Bottom-Up Accounting Model	Potentially best accuracy Accountability Can accommodate all warranty provisions Good trade-off analysis potential	Development expense Complicated Longest time to obtain estimate Needs accurate reliability data

CHAPTER FIVE

ASPECTS OF METHODOLOGIES FOR FURTHER ANALYSIS

Part of our task under this effort was to recommend warranty cost-estimation procedures for Navy programs and to suggest useful areas for further analysis. As a result of our study, we have concluded that further development would be particularly beneficial in three areas: warranty benefit analysis, RIW model enhancement, and data analysis.

5.1 WARRANTY BENEFIT ANALYSIS

The intent of this effort has been to research methodologies for warranty cost estimation, with the estimation concentrating on what the contractor's expenses will be or, equivalently, what is the warranty "should cost" with a "standard" profit. This is also referred to as a fair and reasonable cost, or contractor cost. In theory, the contractor would be willing to provide the service for this amount at a minimum, or at any amount greater than this, with the excess being additional contractor profit. Ideally, the Government would prefer to purchase the service for this amount. Figure 5-1 illustrates this principle, with the contractor cost designated at point Y.

There is another aspect of the cost of a warranty -- that is, the benefit to the Government of having the warranty, also referred to as the warranty value, warranty benefit, or cost-effectiveness of the warranty. The amount of cost benefit of the warranty is illustrated as point X in Figure 5-1. Point X may or may not be greater than point Y, but in general it would be greater. Unless it is greater, there is no cost value to purchasing the warranty and no favorable solution. The Government should be willing to pay amount X or any amount less than that for the service, since it will be buying more in service than it is paying. Any amount less than X is savings to the Government over the life cycle of the system.

Potential solutions to the warranty cost decision, therefore, lie in the range between points Y and X. Any point in this region has benefit to both parties, with more Government savings the closer the warranty price can be negotiated to point Y, and more contractor profit the closer the warranty price is to point X.

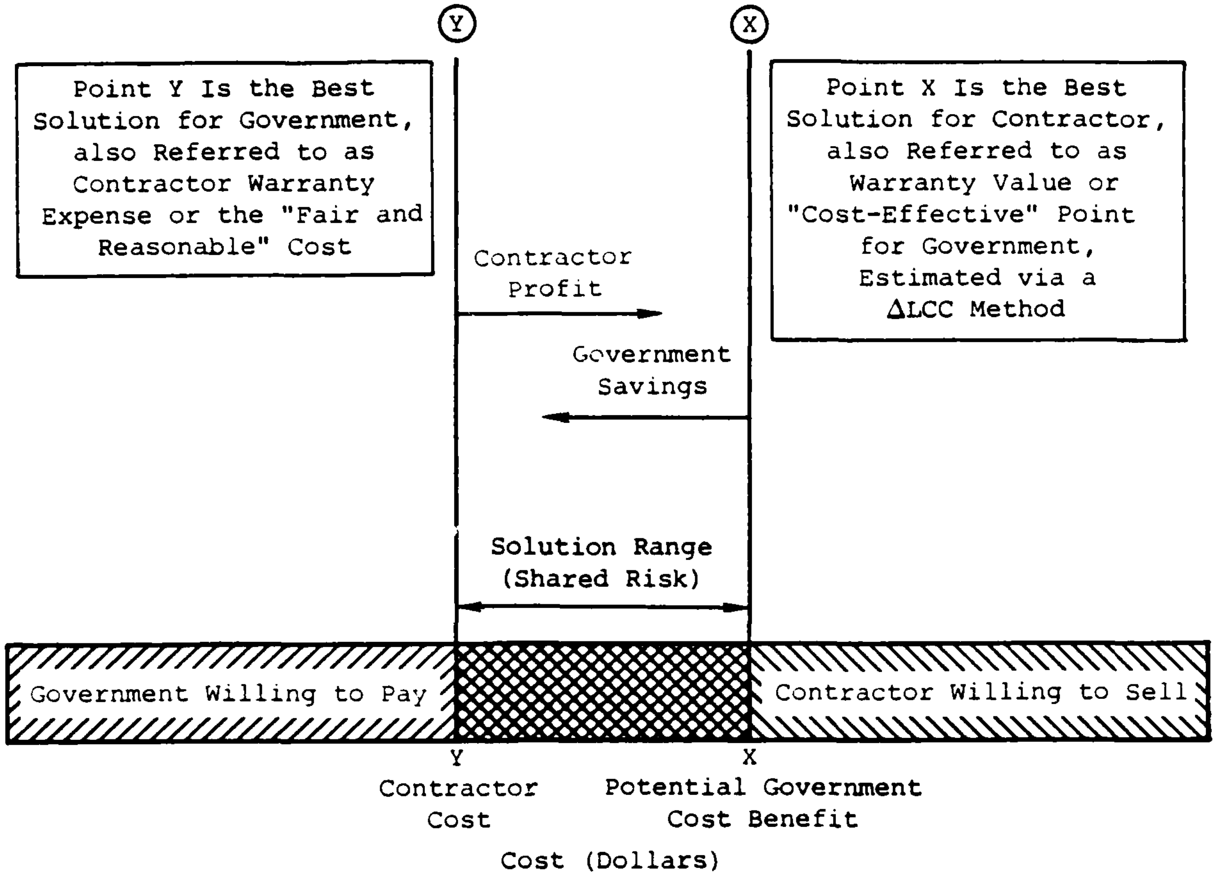

FIGURE 5-1

WARRANTY/GUARANTEE COST BENEFIT

Knowledge of both points is of interest to the Government in order to determine, first, if a warranty is cost-effective, and, if so, what a fair price for the warranty would be. This study addresses methodologies for estimating contractor warranty cost. Methodologies also exist for estimating warranty benefit. For example, one such methodology would be a "ΔLCC" cost-estimation method that estimates full system life-cycle costs, both with and without a warranty, and then calculates the difference. In the course of this study, we have identified and catalogued factors that influence incremental costs of alternative warranty/guarantee provisions for Navy programs. These factors, both direct and indirect, are described in Tables 5-1 and 5-2. Further investigation and analysis of warranty benefit is recommended.

5.2 RIW MODEL ENHANCEMENT

As previously discussed in Chapters Three and Four, only one detailed warranty price/cost-estimation model has been identified that is currently available -- the Air Force RIW pricing model. The model is an accounting-type, bottom-up model. Our assessment indicated that the model includes

TABLE 5-1

MAJOR CATEGORIES OF DIRECT WARRANTY PROGRAM COST FACTORS

Category	Definition
Acquisition Cost	Cost of equipment to be installed
Initial Spares	Cost of recoverable spare units/ modules for base and depot stock
On-Equipment Maintenance	Cost of labor and material for organizational corrective maintenance
Off-Equipment Maintenance	Cost of labor, material, and transportation for intermediate and depot-level maintenance
Test Equipment	Cost of intermediate and depot-level test equipment
Test Equipment Support	Cost of operation and maintenance of test equipment
Training	Cost of training Government personnel in the maintenance and support of the equipment and test equipment
Data	Cost of documentation for operation, maintenance, and support of equipment and test equipment
Inventory Management	Cost of inventory management functions for the equipment
Warranty Price	Cost of warranty charged by the contractor
Administration	Cost of procedures and staff to administer and enforce the warranty

TABLE 5-2

MAJOR CATEGORIES OF INDIRECT WARRANTY PROGRAM COST FACTORS

Category	Definition
Competition	Cost of opportunities in competitive marketplace for acquisition of equipment and parts
Breakout	Cost of opportunities for breakout acquisition of subassemblies
Warranty Bailout	Cost to the Government in the event the contractor fails to fulfill its warranty obligations
Technology	Cost of opportunities in technological advances
Second Sourcing	Cost of opportunities in second sourcing of production units
Readiness	Cost of loss of readiness and failed maintenance capabilities in combat environment

procedures to estimate most of the required cost data items, but that it requires enhancement to incorporate procedures for estimating the costs of design and manufacture guarantee, Government-furnished property (GFP), consignment spares, and warranty price adjustments. The addition of a capability to estimate redesign warranty costs is a top priority. All of these enhancements appear feasible, and it would be more cost-effective to add these capabilities to an existing, proven model than to begin again. Therefore, the enhancement of the RIW pricing model has been identified and recommended as an area for further analysis.

5.3 DATA ANALYSIS

Research into methodologies and procedures for estimating warranty cost does not, strictly speaking, require detailed data analysis. At this early stage of Section 794 implementation in DoD procurements, it is not clear as to the extent that price data actually reflect the warranty cost as opposed to market pressures and other factors. Nevertheless, data analysis is useful in ensuring that these methodologies can be applied

practically and conveniently, in conducting order-of-magnitude studies, and in performing trend analysis. Numerical data are necessary for the follow-on steps of model calibration and validation and for the calculation of default values. As warranty cost-estimation procedures develop, therefore, data collection and analysis will be required at some point.

In the case of the rule-of-thumb ratio methodology, a number of data points will be required to validate that the percentage of unit acquisition cost for warranty cost is in accordance with prices that are actually being submitted and accepted. For the development of warranty CERs, extensive data are essential for the valid statistical development of the relationships. In fact, for parametric models such as the rule-of-thumb ratio and CERs, a key issue is the correspondence of the data with the estimation procedure to predict future warranty costs. Assuming similarity of past warranties to the warranty being estimated, data will be necessary to calibrate and validate the model.

Model calibration and validation, and the calculation of default values will also be required before an accounting model such as the RIW pricing model can be applied. User confidence will depend on good data and proper validation.

Another aspect of warranty cost-estimating methodologies where further study is recommended is trend analysis. A trend analysis, without detailed numerical quantification, indicates the general time relationship of a variable. In the case of warranties, we would be interested in the trend of warranty price for various types of warranty provisions over the years, especially through the 1980s as Section 794 takes effect. We have not collected enough data yet to determine any trends, but this is the opportune time to begin to do so. The data for a trend analysis and determination of stability should become available over time as the contractors gain familiarity and experience with various warranty provisions.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

On the basis of the research performed for this study, ARINC Research Corporation has reached the following conclusions:

- A basic set of warranty provisions meet the requirements of Section 794 for Navy programs. These provisions have been identified and cataloged in Table 2-3 and Figure 4-3.

- Major data items and variables for estimating warranty price/cost have been identified. They are listed in Table 2-5.

- No formal warranty cost-estimation model is currently being used on Navy procurements.

- The Air Force RIW pricing model is the only fully documented DoD model containing detailed warranty cost-estimating equations and algorithms that this study has been able to identify. Our assessment concluded that it could effectively lead to the establishment of uniform Navy procedures for price/cost estimation of Section 794 warranties, because it includes most required variables and is readily capable of enhancement to include all necessary cost items and variables.

- Of the estimation procedures examined, three methodologies are recommended as candidates for warranty cost estimation for Navy programs: rule-of-thumb ratio, warranty cost-estimating relationships (CERs), and bottom-up accounting model. The methodologies are described in Sections 4.2.1, 4.2.2, and 4.2.3 of this report.

6.2 RECOMMENDATIONS

Further analysis and development is recommended in the following areas:

- Warranty Benefit Analysis. A study of methodologies to determine the cost-effectiveness or value of a warranty is recommended. Techniques should be investigated to estimate total system life-cycle costs, both with and without a warranty, and then to calculate the difference.

- RIW Model Enhancement. The Air Force RIW pricing model has been determined to be a detailed, available model for estimation of warranty costs. It will require enhancement to incorporate procedures for estimating the costs of design and manufacture guarantee, Government-furnished property, consignment spares, and warranty price adjustments to be sufficient for Navy programs under the requirements of Section 794. Such enhancement is feasible and recommended.

- Data Analysis. Numerical data are necessary for the follow-on steps of model calibration and validation, as well as for the calculation of default values. Data analysis will be useful in conducting order-of-magnitude studies, performing trend analysis, and ensuring that the methodologies identified in this study can be applied practically and conveniently.

CHAPTER SEVEN

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APPENDIX

WARRANTY COST DATA COLLECTION FORM

This appendix presents a reproduction of a warranty cost data collection form used by ARINC Research Corporation to collect available information on the DoD warranted procurements. The form shows the extent of warranty coverage, the procurement environment, the equipment, and the expected user environment.

For Assistance, Please Call
Mr. Kenneth Tom at (202) 858-4987

DATE ________

WARRANTY/GUARANTEE COST FACTOR DATA
SHEET NO. 1

PROCUREMENT SUMMARY DATA

(NOTE: Copy of Warranty Contract Clause and Price List May be Attached for Procurement Data; then answer only Items 1 through 12 as applicable.)

1. Item Identification: ____________________

2. Contract Agency: ____________________

3. Contract Data
   3.1 Contract No.: ____________________
   3.2 Contractor: ____________________
   3.3 Award Date: ____________
   3.4 Type: FP ____ FPI ____ Other ____________

4. Description of Warranty (Check or enter applicable information)

   4.1 Performance Requirements Verification: Test Demo ____
   Field Demo: ____ Duration (hrs, mos. etc.): ____________
   Other: ____ (Describe in #33)
   4.2 Material and Workmanship: Duration (hrs, mos, etc.) ________
   4.3 Additional Warranties/Guarantees (e.g., MTBF Guarantee, Consignment Spares Obligation, etc) ____ (Describe in #33)

5. Procurement Background
   5.1 Competition
   FSED Y ____ N ____
   Prod. Y ____ N ____
   5.2 Warranty/Guarantee as Source Selection Criteria: Y ____ N ____
   5.3 Contractor Commercial Warranty/Guarantee Experience
   High ____ Nominal ____ Low ____
   5.4 Contractor Weapon System Experience (check off all that apply)
   FSED ____ 1st Prod. ____ F/O ____ None ____
   5.5 Contractor Cooperative Attitude Toward Warranty/Guarantee
   High ____ Nominal ____ Low ____ Don't Know ____
   5.6 When Warranty/Guarantee Priced (check all that apply)
   FSED ____ 1st Prod. ____ F/O ____

6. Major End Items and Prices (Warranted Item and Warranty)

CLIN	Supplies or Services	Quantity	Unit Price

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Mr. Kenneth Tom at (202) 858-4987

DATE

WARRANTY/GUARANTEE COST FACTOR DATA
SHEET NO. 2

PROCUREMENT SUMMARY DATA (continued)

7. Contractor Warranty/Guarantee Obligations (check applicable items)

Correction Material/Workmanship Defects ____
Correction Design/Manufacture Defects ____
Furnishing Warranty Correction Data ____
Loss/Damage in Transit ____
Specified Repair Turnaround ____
SRU Return Permissible for Warranty Work ____
LRU Return Required for Warranty Work ____
Additional Contractor Facilities for Warranty Work ____
Special Equipment for Warranty Work ____
Bonded Storeroom for Warranted Items ____
Warranty Coverage for Modification or Installation of GFP ____
Contractor Pays System Disassembly/Reassembly to Replace Warranted Items ____
Warranty Field Team Required ____
Other (Describe in #33) ____

8. Warranty/Guarantee Adjustments to Contract Price
8.1 For Usage Variations: Y ____ N ____
8.2 For Price Escalation: Y ____ N ____
8.3 Government Right to Repair with Equitable Price Adjustment
Y ____ N ____
8.4 Other ____ (Describe in #33)

9. Cost Responsibilities for Unverified Failures (Test Good)
Contractor ____ Government ____ Shared ____

10. Transportation, Packaging and Handling Costs
10.1 To Repair Facility
Government Pays ____ Contractor Pays ____
10.2 From Repair Facility
Government Pays ____ Contractor Pays ____

11. Warranty/Guarantee Subcontractor(s): Y ____ N ____
(If yes, check applicable)
Subcontractor Warranty/Guarantee Contract with Prime Contractor ____
Subcontractor Warranty/Guarantee Contract with Government ____

12. Additional Comments on Procurement: ____ (Describe in #33)

EQUIPMENT SUMMARY DATA

13. Equipment Maturity
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

14. Technology Risk
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

15. Production Lot Buy
Limited (e.g., LRIP) ____ 1st ____ 2nd ____ 3rd ____ F/O ____

16. Similar Equipment Already Fielded: Yes ____ No ____

17. Expected Field MTBF (Hours): ____________
Value Based on: Spec. ____ Prediction ____ Test/Demo ____
Field Performance ____ Guarantee Value ____

18. R&M Improvement Potential
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

19. Readily Transportable: Y ____ N ____

20. Ruggedization
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

21. Maintenance Complexity
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

22. Contractor Repair Learning Curve
Very High ____ High ____ Nominal ____ Low ____ Very Low ____

23. Additional Comments on Equipment: ____ (Describe in #33)

For Assistance, Please Call
Mr. Kenneth Tom at (202) 858-4987

DATE ____

WARRANTY/GUARANTEE COST FACTOR DATA
SHEET NO. 3

OPERATION DATA SUMMARY

24. Operational Environment Predictable/Known: Y ___ N ___ Partially ___

25. Operational Usage of Weapon System
Very High ___ High ___ Nominal ___ Low ___ Very Low ___

26. Operating Hours Per Warranted Item ____________________

27. Field Testable: Y ___ N ___

28. Control of Unauthorized Maintenance
5.1 Seals: Y ___ N ___
5.2 Warranty Markings: Y ___ N ___

29. Backup Repair Facilities Available: Y ___ N ___

30. Expected Contractor Warranty Administration Efficiency
Very High ___ High ___ Nominal ___ Low ___ Very Low ___

31. Additional Comments on Operation: ___ (Describe in #33)

*** ADDITIONAL DATA SUMMARY ***

32. Point of Contact on Information Provided

Name ____________ Agency/Code ____________ Telephone ____________

33. Additional Comments on Previous Question Items

Item No. Comments

END

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